

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

| | | |
|--|-----------|--|
| (51) International Patent Classification ⁶ : C12Q 1/68, C12P 19/34 | A1 | (11) International Publication Number: WO 96/29430 (43) International Publication Date: 26 September 1996 (26.09.96) |
| (21) International Application Number: PCT/US96/03442 (22) International Filing Date: 13 March 1996 (13.03.96) (30) Priority Data: 08/406,307 17 March 1995 (17.03.95) US (71) Applicants: JOHN WAYNE CANCER INSTITUTE [US/US]; 2200 Santa Monica Boulevard, Santa Monica, CA 90404 (US). NATIONAL GENETICS INSTITUTE [US/US]; Suite 104, 5839 Green Valley Circle, Culver City, CA 90230 (US). (72) Inventors: HOON, Dave, S., B.; 1911 Malcolm Avenue, No. 301, Los Angeles, CA 90025 (US). DOI, Fukashi; 1-1-13, Wakazono Kokum Minami-ku, Kitakyusyu 802 (JP). CONRAD, Andrew, J.; 687 Fifth Avenue, Los Angeles, CA 90049 (US). SCHMID, Peter; 10431 Regent Street, Los Angeles, CA 90034 (US). (74) Agent: HIGHLANDER, Steven, L.; Arnold, White & Durkee, P.O. Box 4433, Houston, TX 77210 (US). | | (81) Designated States: AL, AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |
| (54) Title: DETECTION OF MELANOMA OR BREAST METASTASES WITH A MULTIPLE MARKER ASSAY (57) Abstract A method for the diagnosis of melanoma or breast cancer is provided. In particular, the method provides for the detection of nucleic acids corresponding to multiple melanoma or breast cancer specific markers using template-dependent amplification processes. In one embodiment, the markers used are tyrosinase, MUC18, p97, MAGE-3, β -HCG, MAGE-1 and GalNAc. The methods using these combinations of markers are more sensitive in the detection of tumor cells in patients as compared to single marker assays. | | |

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|----|--------------------------|----|--|----|--------------------------|
| AM | Armenia | GB | United Kingdom | MW | Malawi |
| AT | Austria | GE | Georgia | MX | Mexico |
| AU | Australia | GN | Guinea | NE | Niger |
| BB | Barbados | GR | Greece | NL | Netherlands |
| BE | Belgium | HU | Hungary | NO | Norway |
| BF | Burkina Faso | IE | Ireland | NZ | New Zealand |
| BG | Bulgaria | IT | Italy | PL | Poland |
| BJ | Benin | JP | Japan | PT | Portugal |
| BR | Brazil | KE | Kenya | RO | Romania |
| BY | Belarus | KG | Kyrgystan | RU | Russian Federation |
| CA | Canada | KP | Democratic People's Republic of Korea | SD | Sudan |
| CF | Central African Republic | KR | Republic of Korea | SE | Sweden |
| CG | Congo | KZ | Kazakhstan | SG | Singapore |
| CH | Switzerland | LI | Liechtenstein | SI | Slovenia |
| CI | Côte d'Ivoire | LK | Sri Lanka | SK | Slovakia |
| CM | Cameroon | LR | Liberia | SN | Senegal |
| CN | China | LT | Lithuania | SZ | Swaziland |
| CS | Czechoslovakia | LU | Luxembourg | TD | Chad |
| CZ | Czech Republic | LV | Latvia | TG | Togo |
| DE | Germany | MC | Monaco | TJ | Tajikistan |
| DK | Denmark | MD | Republic of Moldova | TT | Trinidad and Tobago |
| EE | Estonia | MG | Madagascar | UA | Ukraine |
| ES | Spain | ML | Mali | UG | Uganda |
| FI | Finland | MN | Mongolia | US | United States of America |
| FR | France | MR | Mauritania | UZ | Uzbekistan |
| GA | Gabon | | | VN | Viet Nam |

- 1 -

DESCRIPTION**DETECTION OF MELANOMA OR BREAST METASTASES WITH A MULTIPLE MARKER ASSAY**

5

BACKGROUND OF THE INVENTION

Some of the work described in this application was supported by grant number PO1 CA1038 from the National
10 Cancer Institute.

1. Field of the Invention

The present invention relates generally to the field
15 of cancer diagnostic techniques. In particular, the invention relates to the detection of genetic markers indicative of melanoma or breast cancer cells. In one example, detection of multiple markers is achieved by polymerase chain reaction assay.

20

2. Description of the Related Art

Cancers are one of the leading causes of disease, being responsible for 526,000 deaths in the United States
25 each year (Boring et al., 1993). For example, breast cancer is the most common form of malignant disease among women in Western countries and, in the United States, is the most common cause of death among women between 40 and 55 years of age (Forrest, 1990). The incidence of breast
30 cancer is increasing, especially in older women, but the cause of this increase is unknown. Malignant melanoma is another form of cancer whose incidence is increasing at a frightening rate, at least sixfold in the United States since 1945, and is the single most deadly of all skin
35 diseases (Fitzpatrick, 1986).

- 2 -

One of the most devastating aspects of cancer is the propensity of cells from malignant neoplasms to disseminate from their primary site to distant organs and develop into metastases. Despite advances in surgical treatment of primary neoplasms and aggressive therapies, most cancer patients die as a result of metastatic disease. Animal tests indicate that about 0.01% of circulating cancer cells from solid tumors establish successful metastatic colonies (Fidler, 1993).

10

Thus, the detection of occult cancer cells in circulation is important in assessing the level of tumor progression and metastasis. Because subclinical metastasis can remain dormant for many years, monitoring of patients' blood for circulating tumor cells may prove advantageous in detecting tumor progression before metastasis to other organs occurs. Assessment of circulating tumor cells also would provide a rapid monitoring system to determine if a specific therapy is effective.

20

For example, recognition of metastases in tumor-draining lymph nodes (TDLN) now has been shown critical for patient management. It is known that between 25-30 per cent of breast cancer patients with node negative, localized disease will relapse within five years after operative intervention (Henderson et al., 1989). Accurate axillary staging of TDLN in detection of metastases has been an important factor for selecting patients for adjuvant therapy (NIH, 1992; Giuliano, et al., 1995; Giuliano, et al., 1994). Several retrospective studies on breast cancer TDLN demonstrated that analysis of multiple sections of nodes shown to be tumor negative were found to have occult metastases (Bettelheim, et al., 1990; Chen et al., 1991; Neville et al., 1991). The identification of nodes with occult metastases were shown to significantly correlate to

35

- 3 -

poorer prognosis (Bettelheim *et al.*, 1990; Neville *et al.*, 1991).

5 Previous tumor diagnostic techniques have focused on
the detection of tumor associated antigens or on
molecules released by tumor cells (Smart, 1990; Moertel
et *al.*, 1993; Stamey *et al.*, 1989). At best, these
assays only detect tumors with no indication of
metastatic potential or tumor progression. In addition,
10 such assays measure a single antigen whose release is
often proportional to the size of the tumor and they
cannot account for heterogeneity of individual markers in
tumor lesions, both within individual patients or among
patient groups.

15 The recent development of the PCR assay (Mullis and
Faloona, 1987; Erlich, 1989) for detection of occult
metastatic tumor cells in blood using specific markers
has provided a new approach to assess tumor progression
20 (Smith *et al.*, 1991; Naito *et al.*, 1991). In one study,
circulating melanoma cells in blood were detected by PCR
analysis using the tyrosinase gene marker (Smith *et al.*,
1991). Seven melanoma patients with metastatic disease
were analyzed, but only four were positive. Other
25 studies using PCR have been used to detect circulating
tumor cells in melanoma, as well as in breast, prostate
and neuroblastoma cancer patients (Smith *et al.*, 1991;
Datta *et al.*, 1994; Moreno *et al.*, 1992; Naito *et al.*,
1991). These studies, employing a single marker, were
30 limited by their ability to discriminate cancer cells
from normal cells also carrying the marker, thus reducing
specificity and reliability. In addition, tumor
heterogeneity has caused sensitivity problems where a
single, specific marker has been employed.

35

As indicated above, tumors are notoriously
heterogeneous, particularly in advanced stages of tumor

- 4 -

progression (Morton et al., 1993; Fidler and Hart, 1982; Nowell, 1982; Elder et al., 1989; Bystryk et al., 1985). Although tumor cells within a primary tumor or metastasis all may express the same marker gene, the level of specific mRNA expression can vary considerably (Elder et al., 1989). It is, therefore, necessary to develop a detection system that can cope with such heterogeneous targets.

Thus, despite the identification of melanoma and breast cancer markers, these markers cannot individually detect tumor cells in a highly specific and sensitive manner. This is due to the wide phenotypic diversity found in tumor cells at any one time and during disease differentiation. There remains a need to develop a more sophisticated approach, that can accommodate such a biological heterogeneous situation in order to sensitively and specifically detect metastasis and diagnosis disease stage.

3. Summary of the Invention

The present invention seeks to overcome these and other drawbacks inherent in the prior art by providing sensitive and accurate methods for the detection of melanoma or breast cancer cells in a biological sample. The methods provide for the detection of melanoma or breast cancer cells in a biological sample by amplifying at least two nucleic acids from the sample, the nucleic acids being markers for melanoma or breast cancer cells.

The present invention comprises the following steps. A nucleic acid is extracted from a biological sample. The nucleic acid is contacted with a first primer pair that hybridizes to a first melanoma or breast cancer marker nucleic acid. The primers are extended by polymerase to produce an amplification product. This

- 5 -

process is repeated a sufficient number of times to permit detection of the amplification product. Finally, all steps are repeated with the same biological sample and a second primer pair that hybridizes to another
5 melanoma or breast cancer marker nucleic acid.

In preferred embodiments, the method may further comprise preparing at least two pairs of primers complementary to regions of melanoma or breast cancer
10 marker nucleic acids. In another embodiment, the method may further comprise of preparing primer pairs for at least three, four, five, six or even seven melanoma or breast cancer markers.

15 In preferred embodiments of the invention, the markers amplified and detected are selected from the group comprising tyrosinase, MAGE-3, MUC18, p97, MAGE-1, GalNAc and β -HCG. The preferred method of amplification is by reverse transcription and polymerase chain reaction
20 (PCR). In one embodiment of the invention the PCR further comprises nested PCR.

In one embodiment, the nucleic acid is RNA. Preferably, the RNA extracted from a biological sample is
25 total cellular RNA. In a preferred embodiment, the total cellular RNA is converted to DNA prior to amplification.

In certain embodiments of the invention, the biological sample is a body tissue or body fluid. In
30 preferred embodiments, the body tissue is bone marrow aspirate, bone marrow biopsy, lymph node aspirate, lymph node biopsy, spleen tissue, fine needle aspirate, skin biopsy or organ tissue biopsy. Other embodiments include samples where the body fluid is peripheral blood,
35 lymph fluid, ascites, serous fluid, pleural effusion, sputum, cerebrospinal fluid, lacrimal fluid, stool or

- 6 -

urine. In a preferred embodiment, the biological sample is of human origin.

5 In preferred embodiments of the invention, the method includes separation of the amplification product by gel electrophoresis. In other embodiments, the method of separation is by chromatographic techniques. In a preferred embodiment of the invention, hybridization with a labeled probe permits identification of the
10 amplification product following separation.

In further embodiments, the present invention encompasses a kit for use in detecting melanoma or breast cancer cells in a biological sample comprising, pairs of
15 primers for amplifying nucleic acids corresponding to the marker genes, and containers for each of these primers. In preferred embodiments, the kit further comprises enzymes and reagents for the preparation of cDNA's and amplification thereof. In yet more preferred
20 embodiments, the kit further comprises enzymes and reagents for radiochemical or chromophoric labeling of nucleic acids.

4. Detailed Description of the Preferred Embodiments

25

The present invention pertains to a sensitive, multimarker assay to detect occult melanoma or breast cancer cells in the blood of patients with or without clinical evidence of disease. This assay is designed to
30 overcome limitations in existing technologies with respect to both sensitivity and specificity.

In its most general form, the instant invention comprises a method for identification of melanoma or
35 breast cancer cells in a biological sample by amplifying and detecting nucleic acids corresponding to melanoma or breast cancer cell markers. The biological sample can be

- 7 -

any tissue or fluid in which melanoma or breast cancer cells might be present. Preferred embodiments include bone marrow aspirate, bone marrow biopsy, lymph node aspirate, lymph node biopsy, spleen tissue, fine needle aspirate, skin biopsy or organ tissue biopsy. Other
5 embodiments include samples where the body fluid is peripheral blood, lymph fluid, ascites, serous fluid, pleural effusion, sputum, cerebrospinal fluid, lacrimal fluid, stool or urine.

10

Nucleic acid used as template for amplification is isolated from cells contained in the biological sample according to standard methodologies. (Sambrook et al., 1989) The nucleic acid may be genomic DNA or
15 fractionated or whole cell RNA. Where RNA is used, it may be desired to convert the RNA to a complementary cDNA. In a preferred embodiment, the RNA is whole cell RNA and is used directly as the template for amplification.

20

Pairs of primers that selectively hybridize to genes corresponding to specific markers are contacted with the isolated nucleic acid under conditions that permit selective hybridization. Once hybridized, the nucleic
25 acid:primer complex is contacted with one or more enzymes that facilitate template-dependent nucleic acid synthesis. Multiple rounds of amplification, also referred to as "cycles," are conducted until a sufficient amount of amplification product is produced.

30

Next, the amplification product is detected. In certain applications, the detection may be performed by visual means. Alternatively, the detection may involve indirect identification of the product via
35 chemiluminescence, radioactive scintigraphy of incorporated radiolabel or fluorescent label or even via

- 8 -

a system using electrical or thermal impulse signals (Affymax technology, Bellus, 1994).

5 The foregoing process is conducted at least twice on a given sample using at least two different primer pairs specific for two different specific markers. Following detection, one may compare the results seen in a given patient with a statistically significant reference group of normal patients and melanoma or breast cancer
10 patients. In this way, it is possible to correlate the number and kind of markers with various clinical states.

(i) *Melanoma-Specific or Breast Cancer-Specific Markers*

15

While the present invention exemplifies several markers, any marker that is correlated with the presence or absence of melanomas or breast cancer may be used. A marker, as used herein, is any proteinaceous molecule (or
20 corresponding gene) whose production or lack of production is characteristic of a melanoma or breast cancer cell. Depending on the particular set of markers employed in a given analysis, the statistical analysis will vary. For example, where a particular combination
25 of markers is highly specific for melanomas or breast cancer, the statistical significance of a positive result will be high. It may be, however, that such specificity is achieved at the cost of sensitivity, i.e., a negative result may occur even in the presence of melanoma or
30 breast cancer. By the same token, a different combination may be very sensitive, i.e., few false negatives, but has a lower specificity.

As new markers are identified, different
35 combinations may be developed that show optimal function with different ethnic groups or sex, different geographic distributions, different stages of disease, different

- 9 -

degrees of specificity or different degrees of sensitivity. Marker combinations may also be developed, which are particularly sensitive to the effect of therapeutic regimens on disease progression. Patients
5 may be monitored after surgery, hyperthermia, immunotherapy, cytokine therapy, gene therapy, radiotherapy or chemotherapy, to determine if a specific therapy is effective.

10 One particularly useful combination of markers is tyrosinase and p97. Human tyrosinase is an essential enzyme which regulates the production of melanin (Nordlund et al., 1989; Hoon et al., 1993), a group of
15 brown or black pigments in the skin and eyes of humans. More specifically, tyrosinase catalyzes the conversion of tyrosine to Dopa and of Dopa to dopaquinone. p97, also known as melanotransferrin, is a cell surface
sialoglycoprotein that bears some sequence homology to transferrin (Brown et al., 1981; Rose et al., 1986).
20 Like transferrin, p97 binds iron, thereby being implicated in iron metabolism.

There are many other markers that may be used in combination with these, and other, markers. For example,
25 β -human chorionic gonadotropin (β -HCG). β -HCG is produced by trophoblastic cells of placenta of pregnant woman and is essential for maintenance of pregnancy at the early stages (Pierce et al., 1981; Talmadge et al., 1984). β -HCG is known to be produced by trophoblastic or
30 germ cell origin tumors, such as choriocarcinoma or testicular carcinoma cells (Madersbacher et al., 1994; Cole et al., 1983). Also ectopic expression of β -HCG has been detected by a number of different immunoassays in
various tumors of non-gonadal such as breast, lung,
35 gastric, colon, and pancreas, etc. (McManus et al., 1976; Yoshimura et al., 1994; Yamaguchi et al., 1989; Marcillac et al., 1992; Alfthan et al., 1992). Although the

- 10 -

function of β -HCG production in these tumors is still unknown, the atavistic expression of β -HCG by cancer cells and not by normal cells of non-gonadal origin suggests it may be a potentially good marker in the
5 detection of melanoma and breast cancer (Tormey et al., 1977; Tormey et al., 1975).

Another exemplary example of a marker is glycosyltransferase β -1, 4-N-acetylgalactosaminyltransferase (GalNAc). GalNAc catalyzes the
10 transfer of N-acetylgalactosamine by β 1,4 linkage onto both gangliosides GM3 and GD3 to generate GM2 and GD2, respectively (Nagata, et al., 1992; Furukawa et al., 1993). It also catalyzes the transfer of N-
15 acetylgalactosamine to other carbohydrate molecules such as mucins. Gangliosides are glycosphingolipids containing sialic acids which play an important role in cell differentiation, adhesion and malignant transformation. In melanoma, gangliosides GM2 and GD2
20 expression, are often enhanced to very high levels and associated with tumor progression including metastatic tumors (Hoon et al., 1989; Ando et al., 1987; Carubia et al., 1984; Tsuchida et al., 1987a). Gangliosides are also highly expressed in breast cancer cells. The
25 gangliosides GM2 and GD2 are immunogenic in humans and can be used as a target for specific immunotherapy such as human monoclonal antibodies or cancer vaccines (Tsuchida et al., 1987b; Irie, 1985).

30 GalNAc mRNA may be used as a marker of GM2 and GD2 expression and consequently a marker of either melanoma or breast cancer cells. GalNAc is generally not expressed in normal lymphocytes, epithelial cells, melanocytes, connective tissue or lymph node cells. If
35 detected, it is in very low levels.

- 11 -

Other markers contemplated by the present invention include cytolytic T lymphocyte (CTL) targets. MAGE-3 is a marker identified in melanoma cells and breast carcinoma. MAGE-3 is expressed in many melanomas as well
5 as other tumors and is a (CTL) target (Gaugler et al., 1994). MAGE-1 and MAGE-2 are other members of the MAGE gene family. MAGE-1 gene sequence shows 73% identity with MAGE-3 and expresses an antigen also recognized by CTL (Gaugler et al., 1994). MART-1 is another potential
10 CTL target (Robbins et al., 1994) and may also be included in the present invention.

MUC18 is another marker that is useful in the identification of melanoma cells (Lehmann et al., 1989;
15 Lehmann et al., 1987). MUC18 is a cell surface glycoprotein that is a member of the immunoglobulin superfamily and possesses sequence homology to neural cell adhesion molecules (NCAM). Other mucin family members include MUC1, MUC2, MUC3 and MUC4. These were
20 found to be expressed at a high level in certain tumor cell lines (Hollingsworth et al., 1994) and may also be used as markers in the present invention.

Other members of the immunoglobulin superfamily of
25 adhesions molecules associated with the development of melanoma metastasis (Denton et al., 1992) may be utilized in the present invention. Preferred examples include intercellular adhesion molecule-1 (ICAM-1), NCAM, VCAM-1, and ELAM. Another preferred embodiment of the invention,
30 includes cell adhesion molecules associated with other metastatic diseases, such as carcinoembryonic antigen (CEA) and DCC (deleted in colorectal cancer) (Johnson, 1991).

35 Other breast or skin cancer associated proteins and their corresponding nucleic acids may also be utilized in the present invention. Preferred examples include

- 12 -

melanoma antigen gp75 (Vijayasardahi et al., 1990), human
cytokeratin 8 (HKer 8) (Pittman et al., 1993), high
molecular weight melanoma antigen (Natali et al., 1987)
and Keratin 19 (K19) (Datta et al., 1994). This list is
5 not intended to be exhaustive, but merely exemplary, for
the type and number of potential markers which may be
used in the present invention.

Other proteins and their corresponding nucleic acids
10 related to the melanin synthesis pathway may be used as
markers, such as tyrosinase related protein 1 and 2 and
members of the pMel 17 gene family (Kwon et al., 1993).

Preferred embodiments of the invention involve many
15 different combinations of markers for the detection of
melanoma breast cancer cells. Any marker that is
indicative of neoplasia in breast cells or melanocytes
may be included in this invention. However, preferred
embodiments include combinations of tyrosinase, MAGE-3,
20 MUC18, p97, β -HCG, GalNAc and MAGE-1. Table 1, as
disclosed herein, represent partially useful combinations
of markers which may be employed for the detection of
melanoma or breast cancer cells.

- 13 -

Table 1. Preferred Multiple Marker Combinations
 Table 1A. Combinations of Six or Seven Multiple Markers.

| | Tyrosinase | p97 | MUC18 | MAGE3 | β -HCG | GluNAc | MAGE1 |
|----|------------|-----|-------|-------|--------------|--------|-------|
| | + | + | + | + | + | + | + |
| 5 | + | + | + | + | + | + | - |
| | + | + | + | + | + | - | + |
| | + | + | + | + | - | + | + |
| | + | + | + | - | + | + | + |
| | + | + | - | + | + | + | + |
| 10 | + | - | + | + | + | + | + |
| | - | + | + | + | + | + | + |

- 14 -

Table 1B. Combinations of Five Multiple Markers

| | Tyrosinase | p97 | MUC18 | MAGE3 | β -HCG | GluNAc | MAGE1 |
|----|------------|-----|-------|-------|--------------|--------|-------|
| 5 | + | + | + | + | + | - | - |
| | + | + | + | + | - | - | + |
| | + | + | + | - | - | + | + |
| | + | + | - | - | + | + | + |
| | + | - | - | + | + | + | + |
| | - | - | + | + | + | + | + |
| | - | + | + | + | + | + | - |
| 10 | + | + | + | + | - | + | - |
| | + | + | + | - | + | - | + |
| | + | + | - | + | - | + | + |
| | + | - | + | - | + | + | + |
| | - | + | - | + | + | + | + |
| | + | - | + | + | + | + | - |
| | - | + | + | + | + | - | + |
| 15 | + | + | + | - | + | + | - |
| | + | + | - | + | + | - | + |
| | + | - | + | + | - | + | + |
| | - | + | + | - | + | + | + |
| | + | + | - | + | + | + | - |
| | + | - | + | + | + | - | + |
| | - | + | + | + | - | + | + |
| 20 | + | + | + | - | + | + | - |
| | + | + | - | + | + | - | + |
| | + | - | + | + | - | + | + |
| | - | + | + | - | + | + | + |
| | + | + | - | + | + | + | - |
| | + | - | + | + | + | - | + |
| | - | + | + | + | - | + | + |

- 15 -

Table 1C. Combinations of Four Multiple Markers

| | Tyrosinase | p97 | MUC18 | MAGE3 | β -HCG | GluNAc | MAGE1 |
|----|------------|-----|-------|-------|--------------|--------|-------|
| 5 | + | + | + | + | - | - | - |
| | + | + | + | - | - | - | + |
| | + | + | - | - | - | + | + |
| | + | - | - | - | + | + | + |
| | - | - | - | + | + | + | + |
| | - | - | + | + | + | + | - |
| | - | + | + | + | + | - | - |
| 10 | + | + | + | - | - | + | - |
| | + | + | - | - | + | - | + |
| | + | - | - | + | - | + | + |
| | - | - | + | - | + | + | + |
| | - | + | - | + | + | + | - |
| | + | - | + | + | + | - | - |
| | - | + | + | + | - | - | + |
| 15 | + | + | + | - | + | - | - |
| | + | + | - | + | - | - | + |
| | + | - | + | - | - | + | + |
| | - | + | - | - | + | + | + |
| | + | - | - | + | + | + | - |
| | - | - | + | + | + | - | - |
| | - | + | + | + | - | + | - |
| 20 | + | + | - | - | + | + | - |
| | + | - | + | - | - | + | + |
| | - | + | - | - | + | + | + |
| | + | - | - | + | + | + | - |
| | - | - | + | + | + | - | - |
| | - | + | + | + | - | + | - |
| | + | + | - | - | + | + | - |
| 25 | + | - | - | + | + | - | + |
| | - | - | + | + | - | + | + |
| | - | + | + | - | + | + | - |
| | + | + | - | + | + | - | - |
| | + | - | + | + | - | - | + |
| | - | - | + | - | - | + | + |
| | - | - | + | - | - | + | + |

- 16 -

Table 1D. Combinations of Three Multiple Markers

| | Tyrosinase | p97 | MUC18 | MAGE3 | β -HCG | GluNAc | MAGE1 |
|----|------------|-----|-------|-------|--------------|--------|-------|
| 5 | - | - | - | - | + | + | + |
| | - | - | - | + | + | + | - |
| | - | - | + | + | + | - | - |
| | - | + | + | + | - | - | - |
| | + | + | + | - | - | - | - |
| | + | + | - | - | - | - | + |
| | + | - | - | - | - | + | + |
| 10 | - | - | - | + | + | - | + |
| | - | - | + | + | - | + | - |
| | - | + | + | - | + | - | - |
| | + | + | - | + | - | - | - |
| | + | - | + | - | - | - | + |
| | - | + | - | - | - | + | + |
| | + | - | - | - | + | + | - |
| 15 | - | - | - | + | - | + | + |
| | - | - | + | - | + | + | - |
| | - | + | - | + | + | - | - |
| | + | - | + | + | - | - | - |
| | - | + | + | - | - | - | + |
| | + | + | - | - | - | + | + |
| | + | - | - | - | + | - | + |
| 20 | - | - | + | + | - | - | + |
| | - | + | + | - | - | + | - |
| | + | + | - | - | + | - | - |
| | + | - | - | + | - | - | + |
| | - | + | - | - | + | + | - |
| | - | + | - | - | + | + | - |
| | + | + | - | + | + | - | - |
| 25 | - | - | + | + | - | - | + |
| | - | + | + | - | - | + | - |
| | + | + | - | - | + | - | - |
| | + | - | - | + | - | - | + |
| | - | - | + | - | - | + | + |
| | - | + | - | - | + | + | - |
| | + | + | - | + | + | - | - |
| 30 | - | - | - | - | - | - | - |
| | + | + | - | + | + | - | - |

- 17 -

Table 1E. Combinations of Two Multiple Markers

| | Tyrosinase | p97 | MUC18 | MAGE3 | β -HCG | GluNAc | MAGE1 |
|----|------------|-----|-------|-------|--------------|--------|-------|
| | - | - | - | - | - | + | + |
| | - | - | - | - | + | + | - |
| 5 | - | - | - | + | + | - | - |
| | - | - | + | + | - | - | - |
| | - | + | + | - | - | - | - |
| | + | + | - | - | - | - | - |
| | + | - | - | - | - | - | + |
| 10 | - | - | - | - | + | - | + |
| | - | - | - | + | - | + | - |
| | - | - | + | - | + | - | - |
| | - | + | - | + | - | - | - |
| | + | - | + | - | - | - | - |
| 15 | - | + | - | - | - | - | + |
| | + | - | - | - | - | + | - |
| | - | - | - | + | - | - | + |
| | - | - | + | - | - | + | - |
| | - | + | - | - | + | - | - |
| 20 | + | - | - | + | - | - | - |
| | - | - | + | - | - | - | + |
| | - | + | - | - | - | + | - |
| | + | - | - | - | + | - | - |

25 + markers included in the combination; - markers not included.

(ii) *Primers*

30 The term primer, as defined herein, is meant to encompass any nucleic acid that is capable of priming the synthesis of a nascent nucleic acid in a template-dependent process. Typically, primers are oligonucleotides from ten to twenty base pairs in length, but longer sequences can be employed. Primers may be

- 18 -

provided in double-stranded or single-stranded form, although the single-stranded form is preferred.

In most cases, it will be preferable to synthesize
5 desired oligonucleotides. Suitable primers can be synthesized using commercial synthesizers, such as those supplied by Applied Biosystems (Foster City, CA) using methods well known to those of ordinary skill in the art. Where double-stranded primers are desired, synthesis of
10 complementary primers is performed separately and the primers mixed under conditions permitting their hybridization.

Selection of primers is based on a variety of
15 different factors, depending on the method of amplification and the specific marker involved. For example, the choice of primer will determine the specificity of the amplification reaction. The primer needs to be sufficiently long to specifically hybridize
20 to the marker nucleic acid and allow synthesis of amplification products in the presence of the polymerization agent and under appropriate temperature conditions. Shorter primer molecules generally require cooler temperatures to form sufficiently stable hybrid
25 complexes with the marker nucleic acid and may be more susceptible to non-specific hybridization and amplification.

Primer sequences do not need to correspond exactly
30 to the specific marker sequence. Non-complementary nucleotide fragments may be attached to the 5' end of the primer with the remainder of the primer sequence being complementary to the template. Alternatively, non-complementary bases can be interspersed into the primer,
35 provided that the primer sequence has sufficient complementarity, in particular at the 3' end, with the

- 19 -

template for annealing to occur and allow synthesis of a complementary DNA strand.

5 In preferred embodiments, primers may be designed to hybridize to specific regions of the marker nucleic acid sequence. For example, GC rich regions are favored as they form stronger hybridization complexes than AT rich regions. In another example, primers are designed, solely, to hybridize to a pair of exon sequences, with at least one intron in between. This allows for the activity of a marker gene to be detected as opposed to its presence by minimizing background amplification of the genomic sequences and readily distinguishes the target amplification by size.

15

Primers also may be designed to amplify a particular segment of marker nucleic acid that encodes restriction sites. A restriction site in the final amplification product would enable digestion at that particular site by the relevant restriction enzyme to produce two products of a specific size. Any restriction enzyme may be utilized in this aspect. This added refinement to the amplification process may be necessary when amplifying a marker nucleic acid sequence with close sequence similarity to other nucleic acids. Alternatively, it may be used as an added confirmation of the specificity of the amplification product.

25

(iii) Template Dependent Amplification Methods

30

A number of template dependent processes are available to amplify the marker sequences present in a given template sample. One of the best known amplification methods is the polymerase chain reaction (referred to as PCR) which is described in detail in U.S. Patent Nos. 4,683,195, 4,683,202 and 4,800,159, and in Innis et al., 1990, each of which is incorporated herein

35

- 20 -

by reference in its entirety. Briefly, in PCR, two primer sequences are prepared which are complementary to regions on opposite complementary strands of the marker sequence. An excess of deoxynucleoside triphosphates are added to a reaction mixture along with a DNA polymerase, e.g., *Taq* polymerase. If the marker sequence is present in a sample, the primers will bind to the marker and the polymerase will cause the primers to be extended along the marker sequence by adding on nucleotides. By raising and lowering the temperature of the reaction mixture, the extended primers will dissociate from the marker to form reaction products, excess primers will bind to the marker and to the reaction products and the process is repeated. Preferably a reverse transcriptase PCR amplification procedure may be performed in order to quantify the amount of mRNA amplified. Methods of reverse transcribing RNA into cDNA are well known and described in Sambrook et al., 1989. Alternatively, preferred methods for reverse transcription utilize thermostable DNA polymerases. These methods are described in WO 90/07641 filed December 21, 1990. Polymerase chain reaction methodologies are well known in the art.

Another method for amplification is the ligase chain reaction ("LCR"), disclosed in EPO No. 320 308, incorporated herein by reference in its entirety. In LCR, two complementary probe pairs are prepared, and in the presence of the marker sequence, each pair will bind to opposite complementary strands of the marker such that they abut. In the presence of a ligase, the two probe pairs will link to form a single unit. By temperature cycling, as in PCR, bound ligated units dissociate from the marker and then serve as "target sequences" for ligation of excess probe pairs. U.S. Patent No. 4,883,750 describes a method similar to LCR for binding probe pairs to a marker sequence.

- 21 -

Qbeta Replicase, described in PCT Application No. PCT/US87/00880, may also be used as still another amplification method in the present invention. In this method, a replicative sequence of RNA which has a region
5 complementary to that of a marker is added to a sample in the presence of an RNA polymerase. The polymerase will copy the replicative sequence which can then be detected.

An isothermal amplification method, in which
10 restriction endonucleases and ligases are used to achieve the amplification of marker molecules that contain nucleotide 5'-[alpha-thio]-triphosphates in one strand of a restriction site may also be useful in the amplification of nucleic acids in the present invention.
15 Walker et al., 1992, incorporated herein by reference in its entirety.

Strand Displacement Amplification (SDA) is another method of carrying out isothermal amplification of
20 nucleic acids which involves multiple rounds of strand displacement and synthesis, i.e., nick translation. A similar method, called Repair Chain Reaction (RCR) involves annealing several probes throughout a region targeted for amplification, followed by a repair reaction
25 in which only two of the four bases are present. The other two bases can be added as biotinylated derivatives for easy detection. A similar approach is used in SDA. Marker specific sequences can also be detected using a cyclic probe reaction (CPR). In CPR, a probe having a 3'
30 and 5' sequences of non-specific DNA and middle sequence of specific RNA is hybridized to DNA which is present in a sample. Upon hybridization, the reaction is treated with RNaseH, and the products of the probe identified as distinctive products which are released after digestion.
35 The original template is annealed to another cycling probe and the reaction is repeated.

- 22 -

Still another amplification methods described in British Patent Application No. 2,202,328, and in PCT Application No. PCT/US89/01025, each of which is incorporated herein by reference in its entirety, may be used in accordance with the present invention. In the former application, "modified" primers are used in a PCR like, template and enzyme dependent synthesis. The primers may be modified by labelling with a capture moiety (e.g., biotin) and/or a detector moiety (e.g., enzyme). In the latter application, an excess of labeled probes are added to a sample. In the presence of the marker sequence, the probe binds and is cleaved catalytically. After cleavage, the marker sequence is released intact to be bound by excess probe. Cleavage of the labeled probe signals the presence of the marker sequence.

Other nucleic acid amplification procedures include transcription-based amplification systems (TAS), including nucleic acid sequence based amplification (NASBA) and 3SR. Kwoh et al., 1989; Gingeras et al., PCT Application WO 88/10315, incorporated herein by reference in their entirety. In NASBA, the nucleic acids can be prepared for amplification by standard phenol/chloroform extraction, heat denaturation of a clinical sample, treatment with lysis buffer and minispin columns for isolation of DNA and RNA or guanidinium chloride extraction of RNA. These amplification techniques involve annealing a primer which has marker specific sequences. Following polymerization, DNA/RNA hybrids are digested with RNase H while double stranded DNA molecules are heat denatured again. In either case the single stranded DNA is made fully double stranded by addition of second marker specific primer, followed by polymerization. The double-stranded DNA molecules are then multiply transcribed by a polymerase such as T7 or SP6. In an isothermal cyclic reaction, the RNAs are

- 23 -

reverse transcribed into double-stranded DNA, and transcribed once against with a polymerase such as T7 or SP6. The resulting products, whether truncated or complete, indicate marker specific sequences.

5

Davey et al., EPO No. 329 822 (incorporated herein by reference in its entirety) disclose a nucleic acid amplification process involving cyclically synthesizing single-stranded RNA ("ssRNA"), ssDNA, and double-stranded DNA (dsDNA), which may be used in accordance with the present invention. The ssRNA is a first template for a first primer oligonucleotide, which is elongated by reverse transcriptase (RNA-dependent DNA polymerase). The RNA is then removed from the resulting DNA:RNA duplex by the action of ribonuclease H (RNase H, an RNase specific for RNA in duplex with either DNA or RNA). The resultant ssDNA is a second template for a second primer, which also includes the sequences of an RNA polymerase promoter (exemplified by T7 RNA polymerase) 5' to its homology to the template. This primer is then extended by DNA polymerase (exemplified by the large "Klenow" fragment of *E. coli* DNA polymerase I), resulting as a double-stranded DNA ("dsDNA") molecule, having a sequence identical to that of the original RNA between the primers and having additionally, at one end, a promoter sequence. This promoter sequence can be used by the appropriate RNA polymerase to make many RNA copies of the DNA. These copies can then re-enter the cycle leading to very swift amplification. With proper choice of enzymes, this amplification can be done isothermally without addition of enzymes at each cycle. Because of the cyclical nature of this process, the starting sequence can be chosen to be in the form of either DNA or RNA.

35

Miller et al., PCT Application WO 89/06700 (incorporated herein by reference in its entirety) disclose a nucleic acid sequence amplification scheme

- 24 -

based on the hybridization of a promoter/primer sequence to a marker single-stranded DNA ("ssDNA") followed by transcription of many RNA copies of the sequence. This scheme is not cyclic, i.e., new templates are not
5 produced from the resultant RNA transcripts. Other amplification methods include "race" and "one-sided PCR." Frohman, M.A., 1990 and Ohara et al., 1989, each incorporated herein by reference in their entirety.

10 Methods based on ligation of two (or more) oligonucleotides in the presence of nucleic acid having the sequence of the resulting "di-oligonucleotide", thereby amplifying the di-oligonucleotide, may also be used in the amplification step of the present invention.
15 Wu et al., 1989, incorporated herein by reference in its entirety.

(iv) *Separation Methods*

20 Following amplification, it may be desirable to separate the amplification product from the template and the excess primer for the purpose of determining whether specific amplification occurred. In a preferred embodiment, amplification products are separated by
25 agarose, agarose-acrylamide or polyacrylamide gel electrophoresis using standard methods. See Sambrook et al., 1989. In a preferred embodiment, the gel is a 2% agarose gel.

30 Alternatively, chromatographic techniques may be employed to effect separation. There are many kinds of chromatography which may be used in the present invention: adsorption, partition, ion-exchange and molecular sieve, and many specialized techniques for
35 using them including column, paper, thin-layer and gas chromatography (Freifelder, 1982).

- 25 -

(v) *Identification Methods*

Amplification products must be visualized in order to confirm amplification of the marker sequences. One
5 typical visualization method involves staining of a gel with ethidium bromide and visualization under UV light. Alternatively, if the amplification products are integrally labeled with radio- or fluorometrically-labeled nucleotides, the amplification products can then
10 be exposed to x-ray film or visualized under the appropriate stimulating spectra, following separation.

Alternatively, separation may be unnecessary. These methods may be collectively termed Sequencing By
15 Hybridization or SBH (Cantor et al., 1992; Drmanac & Crkvenjakov, U.S. Patent No. 5,202,231). Development of certain of these methods has given rise to new solid support type sequencing tools known as sequencing chips. The utility of SBH in general is evidenced by the fact
20 that U.S. Patents have been granted on this technology.

SBH can be conducted in two basic ways, often referred to as Format 1 and Format 2 (Cantor et al., 1992). In Format 1, oligonucleotides of unknown
25 sequence, generally of about 100-1000 nucleotides in length, are arrayed on a solid support or filter so that the unknown samples themselves are immobilized (Strezoska et al., 1991; Drmanac & Crkvenjakov, U.S. Patent No. 5,202,231). Replicas of the array are then interrogated
30 by hybridization with sets of labeled probes of about 6 to 8 residues in length.

In Format 2, a sequencing chip is formed from an array of oligonucleotides with known sequences of about 6
35 to 8 residues in length (Southern, WO 89/10977; Khrapko et al., 1991; Southern et al., 1992). The nucleic acids of unknown sequence are then labeled and allowed to

- 26 -

hybridize to the immobilized oligos. In another embodiment, hybridization may be detected by electrical or thermal impulse signals (Affymax Technology, Bellus, 1994).

5

In a preferred method, however, visualization is achieved indirectly. Following separation of amplification products, a labeled, nucleic acid probe is brought into contact with the amplified marker sequence. The probe preferably is conjugated to a chromophore but may be radiolabeled. In another embodiment, the probe is conjugated to a binding partner, such as an antibody or biotin, where the other member of the binding pair carries a detectable moiety.

15

In a particularly preferred embodiment, detection is by Southern blotting and hybridization with a labeled probe. The techniques involved in Southern blotting are well known to those of skill in the art and can be found in many standard books on molecular protocols. See Sambrook et al., 1989. Briefly, amplification products are separated by gel electrophoresis. The gel is then contacted with a membrane, such as nitrocellulose, permitting transfer of the nucleic acid and non-covalent binding. Subsequently, the membrane is incubated with a chromophore conjugated probe that is capable of hybridizing with a target amplification product. Detection is by exposure of the membrane to x-ray film or ion-emitting detection devices.

30

One example of the foregoing is described in U.S. Patent No. 5,279,721, incorporated by reference herein, which discloses an apparatus and method for the automated electrophoresis and transfer of nucleic acids. The apparatus permits electrophoresis and blotting without external manipulation of the gel and is ideally suited to

35

- 27 -

carrying out methods according to the present invention.

(vi) *Clinical Stages of Malignant Melanoma*

5 Cancers are staged according to a well-defined, elaborate progressive scale, developed by the American Joint Committee on Cancer.

10 Malignant melanomas can arise in any skin area that contains melanocytes, but body moles, also called pigmented nevi, are particularly vulnerable. Although some moles, especially those on the face and torso, originate in pigment cells, they sometimes contain little pigment and are light in color. All moles are initially
15 benign tumors of varying shape, but it is significant to note that about 20 to 30 percent of all melanomas begin in the pigment cells of moles.

20 Caught early, melanoma is very often curable. On the other hand, melanomas that are not detected until they have invaded even a few millimeters of the deeper layers of skin have a much poorer prognosis. The five-year survival rate varies considerably depending on stage level. For Stage I and Stage II melanoma, the five-year
25 survival rate is over 80%. However, for Stage IV the survival rate is less than 20% (AJCC, .

30 A simplified summary of the scale, developed by the American Joint Committee for the Staging of melanoma is presented in Table 2.

- 28 -

Table 2: Staging of Melanoma

| | |
|----|---|
| | Stage I: Primary site, small tumor Negative lymph nodes No detectable metastases |
| 5 | Stage II: Invasion beyond primary site Lymph nodes negative may have one positive No detectable distant metastases |
| 10 | Stage III: Tumors at regional skin or subcutaneous sites, primarily located to lymph nodes. |
| | Stage IV: Tumor of any size Lymph nodes either positive or negative Distant metastases to multiple sites |
| 15 | Metastasis to a distal organ may or may not result in secondary metastasis to other organs. Since subclinical metastasis can remain dormant for many years, monitoring of a patient's blood for circulating tumor cells may be helpful in detecting tumor progression |
| 20 | before clinically evident metastases to other organs are detected. |

(vii) Clinical Stages of Breast Cancer

25 Many factors appear to influence the chances of
surviving breast cancer. Early detection and treatment
are the most important. The overall five-year survival
rate is about 75 percent for white women and about 63
percent for black women. This rises to nearly 90 percent
30 for women with Stage I or II cancer that is treated while
the cancer is confined to the breast (Scanlon and Strax,
1986).

A simplified summary of the scale, developed by the
35 American Joint Committee for the Staging of Breast Cancer
in 1982, is presented in Table 3.

- 29 -

Table 3: Staging of Breast Cancers

| | |
|----|---|
| | Stage I: Small tumor (less than 2 cm or .78 inches) Negative lymph nodes No detectable metastases |
| 5 | Stage II: Tumor greater than 2 cm but less than 5 cm Lymph nodes negative or Tumor less than 5 cm across Lymph nodes positive |
| 10 | No detectable distant metastases |
| | Stage III: Large tumor (greater than 5 cm) or Tumor of any size with invasion of skin or chest wall or "grave signs" |
| 15 | or Associated with positive lymph nodes in the collarbone area but No detectable distant metastases |
| 20 | Stage IV: Tumor of any size Lymph nodes either positive or negative Distant metastases |

(viii) Kit Components

25

All the basic essential materials and reagents required for detecting melanoma or breast cancer cells in a biological sample, may be assembled together in a kit. This will generally comprise of the preselected primers for two, or more, particular specific markers. Also included may be enzymes suitable for amplifying nucleic acids including various polymerases (RT, Tag, etc.), deoxynucleotides and buffers to provide the necessary reaction mixture for amplification.

35

Such kits will generally comprise, in suitable means, distinct containers for each individual reagent and enzyme as well as for each marker primer pair. Preferred pairs of primers for amplifying nucleic acids correspond to the genes for tyrosinase, MAGE-3, MUC18, p97, MAGE-1, GalNAc and β -HCG.

40

- 30 -

Kits of the present invention, also will typically include a means for containing the reagents in close confinement for commercial sale such as, e.g., injection or blow-molded plastic containers into which the desired reagent are retained. Other containers suitable for conducting certain steps of the disclosed methods also may be provided.

5. Examples

10

The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

25

EXAMPLE I

Detection of Multiple Marker RNA Expression in Melanoma Cells

A. MATERIALS AND METHODS

30

(i) Melanoma cell lines

Melanoma cell lines M10, M12, M24, M101, Mke, Mst, Mmu, Mka, and Mkn were established and characterized at the John Wayne Cancer Institute (JWCI). Cells were grown in RPMI 1640 plus 10% fetal calf serum (heat-inactivated) (Gemini, Calabasas, CA) plus penicillin and streptomycin

35

- 31 -

(GIBCO, Long Island, NY) in T75 cm² flasks. Adherent cell lines were routinely passaged by trypsinization every 3-4 days (Hoon et al., 1993). For PCR studies, cell lines were used when 75-85% confluent.

5

(ii) *Blood preparation and RNA extraction*

Peripheral blood lymphocytes (PBL) were obtained from the buffy coat of 15 ml of blood from healthy normal donors. The cells were washed by centrifugation for 5 min.

Total cellular RNA was extracted using the UltraSpec isolation system (Biotechx, Houston, TX) or Tri-Reagent isolation system (Molecular Research Center, Inc., Cincinnati OH) as described by the manufacturer. For UltraSpec, the cells were lysed in 2 ml of UltraSpec RNA reagent by repetitive pipetting and placed in ice for 5 min. Four hundred μ l of chloroform was added and mixed rigorously for 15 sec and placed on ice for 5 min. The solution was centrifuged at 12,000 X g at 4°C for 15 min. The upper phase was transferred into a RNase-free eppendorf tube, 1 volume of isopropanol was added and the solution was precipitated at 4°C for 10 min. The tube was centrifuged at 12,000 g at 4°C for 20 min. The sample was washed with 70% ethanol, dried, and resuspended in 50 μ l of DEPC (diethylpyrocarbonate)-treated Tris-EDTA (TE) buffer.

For Tri-Reagent, the cells were lysed in 1 ml of Tri-Reagent by repetitive pipetting and were placed on ice for 5 min. Two hundred μ l of chloroform was added and mixed vigorously for 15 sec and incubated at room temperature for 5 min. The solution was then centrifuged at 12,000 X g at 4°C for 15 min. The upper aqueous phase was transferred into an RNase-free eppendorf tube, equal volume of isopropanol was then added and the nucleic acid

- 32 -

was allowed to precipitate at room temperature for 10 min. The tube was then centrifuged as 12,000 X g at 4°C for 10 min. The sample was washed twice with 70% ethanol, vacuum-dried, and resuspended in 10mM Tris-HCl with 1 ml EDTA solution (pH 7.4). The concentration of total RNA was determined using a Beckman spectrophotometer. One μ g of total RNA was used in the PCR assay to detect mRNA.

10 All extraction procedures for each specimen were carried out separately in a designated laminar flow hood under sterile conditions to avoid potential RNA cross-contamination. PCR reagent set up and post-PCR gel electrophoresis were carried out in separate rooms to avoid potential RNA cross-contamination.

(iii) Oligonucleotide primers and probes

Oligonucleotide primers were synthesized and purified at the Molecular Biology Institute Core Facility, UCLA. Oligonucleotide 5-' and 3'-primers for individual genes were as follows: MAGE-3 primers were 5'-GAAGCCGGCCAGGCTCG-3' (SEQ ID NO: 1) and 5'-GGAGTCCTCATAGGATTGGCTCC-3' (SEQ ID NO: 2); MUC18 primers were 5'-CCAAGGCAACCTCAGCCATGTC-3' (SEQ ID NO: 3) and 5'-CTCGACTCCACAGTCTGGGACGACT-3' (SEQ ID NO: 4); MUC18 nested primers were 5'-GTCATCTTCCGTGTGCGCCA-3' (SEQ ID NO: 5) and 5'-GTAGCGACCTCCTCAGGCTCCTTAC-3' (SEQ ID NO: 6); tyrosinase were 5'-TTGGCAGATTGTCTGTAGCC-3' (SEQ ID NO: 7) and 5'-AGGCATTGTGCATGCTGCTT-3' (SEQ ID NO: 8); tyrosinase nested primers were 5'-GTCTTTATGCAATGGAACGC-3' (SEQ ID NO: 9) and 5'-GCTATCCCAGTAAGTGGACT-3' (SEQ ID NO: 10); and p97 primers were 5'-TACCTGGTGGAGAGCGCGCCGCTC-3' (SEQ ID NO: 11) and 5'-AGCGTCTTCCCCATCAGTGT-3' (SEQ ID NO: 12). The amplification products of MAGE-3, MUC18, MUC18 "nested," tyrosinase, tyrosinase "nested" and p97 were 423, 437, 262, 284, 207 and 286 bp, respectively.

- 33 -

(iv) Reverse Transcription and Polymerase chain reaction (RT-PCR)

The RT-PCR assay was performed as previously described with some modifications (Hoon et al., 1993). An oligo (dT)₁₅ primer was employed for the reverse transcription step, to produce cDNA and guarantee its amplification over genomic DNA. The reverse transcription (RT) mixture consisted of 4 μ l 25 mM MgCl₂, 2 μ l 10X RT buffer, 4 μ l 10 mM dinucleotide triphosphate mixture, 0.5 μ l RNAs in (40 U/ μ l), 1 μ l AMV reverse transcriptase (9 U/ μ l), and 1 μ l oligo(dT)₁₅ primer (1.5 μ g/ μ l). Three μ g of sample RNA was added to the RT mixture and H₂O was added to bring the volume up to 20 μ l. All reagents were obtained from Promega (Madison, WI). The reaction was incubated at 42°C for 2 hr, 99°C for 5 min, and on ice for 5 min.

The PCR mixture consisted of 10 μ l 10X PCR buffer (Perkin Elmer Cetus, Norwalk, CT), 8 μ l 10 mM dNTPs mixture, 1 μ l 5'-primer (100 pmol/ μ l), 1 μ l 5'- and 3'-primer, 0.5 μ l AmpliTaq 5 U/ μ l (100 mM Tris-HCl, pH 8.3, 500 mM KCl, 15 mM MgCl₂, 0.01% gelatin, Perkin Elmer Cetus) and 20 μ l of RT mixture. Sterile, double-distilled H₂O was added to the mixture to bring it up to 100 μ l. The mixture was overlaid with mineral oil. The PCR conditions were set up as follows: 95°C for 5 min followed by 95°C for 70 sec, 52°C for 70 sec, 72°C for 70 sec for 40 cycles, and 72°C for 10 min extension time and soaked at 4°C. The PCR reaction was performed in an OmniGene temperature cycler (Hybaid, Middlesex, England).

To assess nested primers to a particular gene the PCR mixture after completion through the PCR cycling was added (10 μ l) to 10 μ l of 10x PCR buffer, 8 μ l of 10 mM dNTPs, 1 μ l of 5'-nested primer (100 pmol/ μ l), 1 μ l of 3'-nested primer (100 pmol/ μ l) and 0.5 μ l of AmpliTaq

- 34 -

polymerase (5 U/ μ l). The volume of the mixture was brought up to 100 μ l. The PCR cycling was performed as for the first reaction except the annealing temperature was 55°C. The preparation of PCR mixture for the
5 temperature cyler was carried out in a designated PCR room in a specified laminar flow hood.

The PCR amplification product was detected by electrophoresis on a 2% agarose gel (GIBCO BRL, Grand
10 Island, N.Y.) and visualized by ethidium bromide staining under ultra violet light. An ϕ X174RF DNA/Hae III fragment DNA ladder (BRL) was used as a size reference marker for all assays.

15 B. RESULTS

The screening process involved examining 10 established melanoma cell lines (10^6 cells/line) and 39 normal PBL (10^7 cells/blood draw) as controls. In Table
20 4, the expression of these markers is shown for melanoma cells and PBL. A positive reaction was considered as a visible specific PCR amplification product by gel electrophoresis stained with ethidium bromide.

25 **Table 4**
PCR analysis of melanoma marker genes

| Marker gene | Melanoma cell lines | PBL |
|-------------|---------------------|------|
| Tyrosinase | 9/10 | 0/39 |
| p97 | 10/10 | 0/39 |
| 30 MAGE-3 | 8/10 | 0/39 |
| MUC18 | 10/10 | 2/39 |

RNA was extracted from melanoma and PBL and assessed for expression of individual markers by PCR. Data presented as positive cell lines or PBL over total
35 number of specimens assessed. Positive PCR refers to PCR amplification product assessed by gel electrophoresis.

- 35 -

All four markers were transcribed in all the melanoma lines, except for MAGE-3. A melanoma cell line expressing all four markers would produce cDNA PCR products of size; 284 base pairs (bp), 286 bp, 423 bp and 437 bp (tyrosinase, p97, MAGE-3 and MUC18 respectively) as observed after electrophoresis through an agarose gel with ethidium bromide staining and compared with DNA size markers. In one melanoma cell line, tyrosinase expression by PCR was negative; however, when nested PCR for tyrosinase was performed tyrosinase gene expression was detected. There was no detection of melanoma markers in PBL from 39 normal donors, except two donors which were positive for MUC18 gene transcription. These individuals were tested multiple times from separate blood draws and always remained positive for MUC18. This indicated they were not false positive results due to PCR contamination or contamination from normal tissue during blood drawing.

In all assays, MUC18 nested primer PCR was performed; this procedure increased the sensitivity to allow verification and amplification of weak bands produced by PCR with only MUC18 primers. Melanoma cell lines and PBL were tested at least twice to verify specificity. Respective controls in each assay included samples with positive RNA for the gene being assessed, PCR reagents and primers without RNA, human tumor cell lines which were negative for individual gene expression, and β -actin gene expression.

30

MAGE-1, a gene family member of MAGE-3, also was tested and found to be transcribed in less than 50% of the melanoma cell lines. It was decided not to use this marker for melanoma, since MAGE-3 is more highly expressed in melanomas and MAGE-3 is usually found when MAGE-1 is expressed (Gaugler et al., 1994). Expression

35

- 36 -

of both genes were not detected in PBL from normal volunteer donors.

EXAMPLE II

5 Sensitivity of Multiple Melanoma Markers

A. MATERIALS AND METHODS

10 RNA was isolated and quantitated from melanoma cell lines positive for individual markers. Specific marker PCR analysis was then carried out on serial diluted RNA as described in Example I.

15 (i) Southern blot analysis

 After electrophoresis of PCR amplification products, agarose gels were transferred overnight onto nitrocellulose membrane (Schleicher & Schull, Keene, N.H.) with 20X SSC buffer as previously described. The
20 cDNA was then UV-crosslinked onto the membrane and hybridized overnight with a digoxigenin labelled probe (Morisaki et al., 1992). After hybridization, the membrane was washed in 2X SSC, 0.1% SDS for 10 min. at room temperature and then in 0.1X SSC, 0.1% SDS for 30
25 min. at 68°C to remove nonspecific binding (Sambrook et al., 1989). Specific binding was detected using anti-digoxigenin, alkaline phosphatase-conjugated antibody as described by the manufacturer (Genius Kit; Boehringer Mannheim, Indianapolis, IN). Tyrosinase probes were
30 either prepared, full-length from PCR cDNA products using the outermost PCR oligonucleotide primers, or 2K bp probes were Eco RI digested from plasmids containing the tyrosinase gene sequence (Kwon et al., 1987). All other probes used in Southern blotting, were prepared from PCR
35 cDNA products using the outermost oligonucleotide primers.

- 37 -

Gel electrophoresis and Southern blotting also was performed automatically using the Automated Electrophoresis System, National Genetics, Inc. and U.S. Patent No. 5,279,721. See above.

5

B. RESULTS

In general, all markers could be detected at picogram levels of RNA by visual examination of gel-electrophoresed PCR amplification products stained with ethidium bromide. RNA from melanoma cell lines were diluted in a series from 1 to 10^{-9} μ g and assessed for markers tyrosinase, p97, MUC18, and MAGE-3. Sensitivity varied for individual lines with different levels of gene expression. In general, mRNA for p97, MUC18, and MAGE-3 was detected around 10-100 pg by PCR. Tyrosinase mRNA could be detected at 10-100 fg by PCR.

Specificity of the amplification products was demonstrated by Southern blotting with respective specific probes (tyrosinase, p97). Sensitivity of the PCR assay could be enhanced 10- to 100-fold using PCR followed by probe blotting. Nested PCR for tyrosinase enhanced detection levels 10-100 fold above PCR for tyrosinase. However, nested PCR for MUC18 enhanced results about 10-fold compared to standard PCR for MUC18.

EXAMPLE III

Detection of Melanoma Cells Mixed With PBL *in vitro*

30

A model system mimicking circulating melanoma cells in blood was developed. In this assay, system 10^7 normal PBL were mixed with serial dilutions of melanoma cells (10^6 to 1 cell) and assessed by PCR for individual gene markers. The PCR amplification products were then assessed by ethidium bromide staining of gels and by Southern blot analysis. RT-PCR amplification was also

- 38 -

performed on RNA extracted from 10^7 PBL and 10^1 melanoma cells, as controls. Southern blot analysis performed for tyrosinase verified the specificity of the PCR amplification product and demonstrated enhanced
5 sensitivity. Materials and methods were as described in Examples I and II.

Gel electrophoresis or nested primers analysis demonstrated that melanoma cells could be detected at
10 about 1 cell in 10^7 PBL for tyrosinase, p97 and MUC18. PBL controls were negative for individual markers in both gel staining and Southern blot analysis and in both standard and nested PCR. Specific dilutions of melanoma cells, were also analysed, in 50 million PBL and
15 demonstrated that about 1-5 melanoma cells could be detected in 50 million PBL with nested primer tyrosinase PCR followed by probing with tyrosinase cDNA.

To demonstrate the sensitivity and reproducibility
20 of detecting 1 melanoma cell in 10 million PBL, a Poisson distribution analysis was carried out. In 8 of 11 samples, a positive PCR amplification product developed by tyrosinase PCR was detected by gel electrophoresis. The level of detection was enhanced >90% when tyrosinase
25 nested PCR primers or Southern blot analysis with tyrosinase probe was performed.

- 39 -

EXAMPLE IV

Assessment of Circulating Melanoma Cells
in Patients Blood5 **A. MATERIALS AND METHODS** *(i) Patients*

 All melanoma patient with complete documented
10 physical and medical histories were accrued from JWCI.
 Melanoma patients studied were AJCC (American Joint
 Committee on Cancer) stage I, II, III and IV. Patients
 assessed were NED (no evidence of clinical disease), AWD
 (alive with clinical disease) or EXP (expired during
15 follow-up). The accrual and study of patients was
 carried out in a double-blind fashion. The patients'
 disease status was not known to the individual running
 the PCR assay nor the analyzer of the PCR data. Clinical
 disease status was documented at the time of blood
20 drawing and again at 8-15 month follow-up period. PCR
 data results were not known to individuals recording the
 patient status during the follow-up period.

 Fifteen ml of blood was obtained from patients and
25 collected in sodium citrate tubes. All blood was drawn
 in the John Wayne Cancer Clinic using the same procedure.
 Blood was drawn after written consent was obtained from
 the patient. The protocol for the study was approved by
 the Saint John's Hospital and John Wayne Cancer Institute
30 Human Subjects Committee. Tubes were centrifuged for 20
 min at 2000 x g. The buffy coat was carefully removed
 and diluted in double distilled water. The cells were
 washed by centrifugation for 5 min. All other materials
 and methods were performed as described in Example I and
35 II.

- 40 -

(ii) Protocol

Materials and methods were as described in Examples I and II. PBL from melanoma patients were examined using an optimized PCR assay detection system. The protocol was as follows: PCR assays were performed to detect transcripts of tyrosinase, p97, MAGE-3, and MUC18. All melanoma patients were subjected to all four tests. If the sample was negative for tyrosinase or MUC18, nested PCR was performed with respective primers. If the PBL specimen was negative in the PCR assay for tyrosinase nested primers and p97 markers, then Southern blot analysis would be performed with respective probes. PBLs negative for all the markers and tests were considered as true negatives.

Initially, PBL isolated by Ficoll-hypaque gradient centrifugation were compared to buffy coat isolated PBL. In the analysis, buffy coat isolated cells appeared better for the detection of circulating melanoma cells in blood by PCR.

B. RESULTS

A summary of the analysis of blood specimens by PCR using multiple markers, as assessed by ethidium bromide stained gels, is shown in Table 5. The greatest number of positive patients was observed with MUC18 (73%), with tyrosinase (59%), p97 (54%) and MAGE-3 (10%) identifying few. Analysis with nested primers of tyrosinase versus tyrosinase primers significantly increased the number of positive patients from 2 to 57. Further analysis of p97-negative and tyrosinase-negative patients with respective specific probes significantly increased the number of positive patients. The most significant increase was observed by Southern blotting with the p97 probe. Six

- 41 -

patients were positive for all four markers. All six patients were stage IV.

Table 5

5 **Analysis of melanoma patients using multiple
marker PCR assay**

| Assays | Number of patients positive | | | |
|-----------------|-----------------------------|------------|--------|-------|
| | p97 | tyrosinase | MAGE-3 | MUC18 |
| PCR | 16 | 2 | 12 | 80 |
| 10 Nested PCR | - | 57 | - | 87 |
| cDNA blot | 49 | 12 | - | - |
| Total patients | 65 | 71 | 12 | 87 |

15 Melanoma patients (120) were evaluated. PCR and cDNA blot refer to assays positive for individual marker genes. Nested PCR refer to specimens tested negative for tyrosinase PCR, and + or - for MUC18 PCR that become positive after nested PCR. cDNA blot refers to patients tested that were negative for either PCR or nested PCR and became positive after cDNA blotting.

20 The PCR analyses were correlated with disease stage and status (AWD & EXP, NED) of patients. The follow-up time for clinical status after blood drawing for PCR analysis was 8-15 months. In the study, there were 4,
25 18, 32, and 66 Stage I, II, III, and IV patients, respectively. The majority of the patients in individual Stages II to IV were PCR positive. Table 6.

- 42 -

Table 6
PCR positive patients correlation to
Disease status patient status

| | AJCC | AWD & EXP | NED |
|----|-------------------|----------------|-------------|
| 5 | Stage | | |
| | I | NP | 1/4 |
| | II | NP | 16/18 |
| | III | 5/6 | 23/26 |
| | IV | 46/48 | 17/18 |
| 10 | Total positive | 51/54 (94%) | 57/66 (86%) |

15 Values represent patients PCR positive (1 or more markers) over total patients evaluated. NP refers to no patients. AWD & EXP refer to patients AWD and those who were AWD during the blood draw and expired (EXP) during the follow-up period.

20 The detection of PCR markers was correlated with the Breslow thickness and Clark level of the primary melanoma, after it had been surgically removed. The latter two factors play a role in determining the patients prognosis (Breslow, 1970; Morton et al., 1993). Breslow thickness has been shown to correlate very well with disease progression. Breslow thickness was divided
 25 into subgroups of 0.75 mm or less, >0.75 mm to 1.49 mm, ≥1.5 mm to 3.0 mm and >3.0 mm. However, there was no significant correlation of Breslow thickness and detection of PCR markers. Although the majority of the patients were either Clark's level 3 or 4, no significant
 30 pattern was observed for Clark's level and number of positive PCR markers. Neither the number of tumor-positive regional lymph nodes nor the sites of distal metastases significantly correlated with the number of positive PCR markers.

35

The lack of correlation between primary melanoma Breslow thickness and Clark's level with the number of PCR positive markers may be due to the fact that tumor

- 43 -

progression is no longer dependent on these initial pathological parameters of the primary tumor once it has been removed.

5

EXAMPLE V**Statistical Analysis**

10 To assess the difference between using tyrosinase alone as a marker and using tyrosinase, MUC18, p97 and MAGE-3 together, a coefficient in level for small sample proportion analysis was performed. Assessment of significance of disease stage to PCR data that was analyzed is summarized below:

15 n = 120 Stage I = 4 NED = 65
 Stage II = 18 AWD = 38
 Stage III = 32 EXP = 17
 Stage IV = 66

20 Of the 120 patients, 49 tested negative for tyrosinase. 42 of these tested positive for at least one of the other three markers (MUC18, P97, MAGE-3). This improvement is statistically significant at the 99% confidence level. It can therefore, be concluded that
25 the four marker PCR assay is more sensitive than the single marker (tyrosinase) assay.

30 Next, an attempt to correlate a patient's disease stage (I, II, III, or IV) and the number of positive markers (0-4) was undertaken. Table 7 shows the breakdown.

- 44 -

Table 7
Number of PCR markers correlated to
stage and disease status

| Disease stages | Patients Number of positive markers | | | | | Total Patients |
|----------------|--|----|----|----|---|-------------------|
| | 0 | 1 | 2 | 3 | 4 | |
| I | 3 | 0 | 0 | 1 | 0 | 4 |
| II | 2 | 6 | 5 | 5 | 0 | 18 |
| III | 4 | 5 | 15 | 8 | 0 | 32 |
| IV | 3 | 15 | 23 | 18 | 7 | 66 |
| Total | 12 | 26 | 43 | 32 | 7 | 120 |

Positive markers refer to detection of tyrosinase, p97, MUC18 and MAGE-3 by either PCR, nested PCR or Southern blotting.

The results show a positive correlation between stage and the number of positive markers, $p = 0.0025$, i.e., as stage increases, the proportion of positive markers also seems to increase.

In the follow-up period after blood drawing, patients were divided into those with clinical evidence of disease progression and those with no evidence. The number of patients positive for 0 to 4 PCR markers was correlated to disease progression. The relationship between progression and the number of positive markers also was assessed. Analysis showed that there was a significant correlation ($p < 0.05$) between number of positive markers and disease progression. Table 8.

- 45 -

Table 8
Number of PCR markers correlated to
progression of disease

| | 0 pos | 1 pos | 2 pos | 3 pos | 4 pos | TOTAL |
|----------------|-------|-------|-------|-------|-------|-------|
| No Progression | 9 | 13 | 32 | 17 | 2 | 73 |
| Progression | 3 | 13 | 11 | 15 | 5 | 47 |
| TOTAL | 12 | 26 | 43 | 32 | 7 | 120 |

Thus, although tyrosinase has been used as a marker in a previous report, the studies disclosed herein indicate that tyrosinase alone is not always sensitive in detecting circulating melanoma cells. The use of more than one marker can verify the presence of occult melanoma cells and significantly increase the sensitivity of detecting melanoma cells that express few or no copies of tyrosinase mRNA. The study demonstrated that using four markers was significantly better than tyrosinase alone. In addition, the number of markers detected in individual patients correlated, significantly, with stage and disease progression. This higher expression of individual marker genes indicates, that there is an increase in the heterogeneity of tumor cells or an increase in the number of cells in circulation, at advance stages of disease.

Overall, the level of detection was similar for tyrosinase and p97 markers. MUC18 marker was the most frequently detected whereas, MAGE-3 was the lowest. Although MAGE-3 is expressed in cell lines and biopsies in higher frequency, the number of mRNA copies in a single tumor cell is likely to be very low. This may be related to the state of the cell or clonal phenotype during circulation in the blood.

- 46 -

EXAMPLE VI**Detection of β -HCG mRNA Expression in Melanoma Cells****A. MATERIALS AND METHODS**

5

(i) Melanoma Cell Lines

Twenty-four melanoma cell lines were established and characterized at John Wayne Cancer Institute as previously described (Hoon et al., 1991). Cell lines were cultured and passaged as described in Example I.

(ii) RNA extraction

15 Total cellular RNA was extracted, isolated and purified using Tri-Reagent according to the manufacturer's protocol (Molecular Research Center, Inc. Cincinnati, OH) and described in detail in Example I. Cells from melanoma lines were lightly trypsinized and collected from tissue culture flasks. Biopsy specimens if cryopreserved were rapidly thawed and kept in a ice water bath. Tumor biopsies were kept in a ice water bath when being minced. All RNA extraction was carried out in a sterile designated laminar flow hood with RNase free labware. Purified RNA was quantitated and assessed for purity by UV spectrophotometry.

(iii) Oligonucleotide primers and Probes

30 Oligonucleotide primers were synthesized and purified at the Molecular Biology Institute Core Facility, UCLA. The β -HCG primer sequences were as follows: 5' primer was 5'-ATGCCACCCTGGC TGTGGAGAA-3' (SEQ ID NO: 13) and the 3' primer was 5'-GGGAGTCGGGATGGACTTGGAA-3' (SEQ ID NO: 14). The RT-PCR cDNA product was 367 bp. The 5' primer has only one mismatch with the β -luteinizing hormone (LH, see below)

- 47 -

while the 3' primer is homologous to both β -HCG AND β -LH coding regions. A full-length, PCR product, amplified from β -HCG DNA, was used a probe for Southern blot analysis.

5

The sequences of α -HCG primers were derived from the GenBank; 5'-AAAGGAGCGCCATGGATTAC-3' (SEQ ID NO: 15); and 3' primer, 5'-CCATTACTGTGACCCTGTTA-3' (SEQ ID NO: 16). The α -HCG PCR cDNA product was 297 bp. The primer
10 sequences for β -HCG/LH receptors were 5' primer, 5'-CCCGATGTGCTCCTGAACCAGA-3' (SEQ ID NO: 17); and 3' primer, 5'-GCTGACACCGACAAGGGGCAA-3' (SEQ ID NO: 18). The RT-PCR cDNA product for β -HCG/LH receptors was 496 bp. The β -actin primer sequences were as follows: 5' primer was
15 5'-GGAGCAATGATCTTGATCTTC-3' (SEQ ID NO: 21) and the 3' primer was 5'-CCTTCCTGGGCATGGAGTCCTG-3' (SEQ ID NO: 22). The RT-PCR product was 201 bp. The tyrosinase and MAGE-3 primers were the same as described in Example I.

20 (iv) RT-PCR assay

The RT-PCR assay was carried out as previously described (Morisaki et al., 1992, and in Example I). Briefly, reverse transcription was carried out with oligo
25 (dT)₁₅ primer and AMV reverse transcriptase with 5 ug of RNA and incubated for 2 hr at 42°C and 99°C for 5 min. The RT-PCR conditions were set up as follows: 95°C for 5 min followed by 95°C for 1 min, 65°C for 1 min, 72°C for 1 min, and 72°C for 10 min for final primer extension
30 sequence and performed in an OmniGene thermocycler (Hybaid, Middlesex, England).

- 48 -

(v) *Restriction digestion*

β -HCG is a gonadotropin hormone composed of an α - and β -subunit (Giuliano, et al., 1995; Fiddes et al., 1979; Boorstein et al., 1982). The amino acid sequence of α -HCG is essentially indistinguishable from those of the other human gonadotropin hormones, such as follicle-stimulating, luteinizing, and thyroid-stimulating hormones (Fiddes et al., 1979; Pierce et al. 1981). However, the β -HCG subunit is different amongst the other hormone subunits except for the β -LH subunit; they share 82% common amino acid sequence (Talmadge et al., 1984). The β -subunit of HCG to date has been shown to consist of cluster of 6 related genes linked closely to the β -LH single gene (Bo et al., 1992). Since the β -HCG and β -LH are highly homologous it is not possible to design a primer sequence absolutely specific to β -HCG.

However, the β -HCG PCR cDNA product has a unique *Sty* I restriction site that is not present in the β -LH PCR cDNA product. Digestion of PCR products with this enzyme allows β -HCG to be distinguished from β -LH. RT-PCR cDNA product was incubated with 10X NEBuffer 3 (New England BioLabs, Beverly, MA) and *Sty* I (10 U/ml) (New England Biolabs) and the mixture was incubated overnight at 37°C. The endonuclease digested product mixture was run on a 2% agarose gel and stained with Etbr. β -HCG RT-PCR cDNA product digested with *Sty* I produces a 271 and 96 bp band. If no digestion occurred the reaction was repeated at least twice to confirm.

(vi) *Southern blotting*

RT-PCR cDNA products run on a 2% agarose gel were denatured and transferred overnight onto nylon membrane (Micron Separations, Inc.) as previously described in Example II. β -HCG cDNA probe was prepared by PCR,

- 49 -

purified and digoxigenin labelled as described in Example II.

B. RESULTS

5

Assessment of β -HCG expression in cells by molecular techniques has been difficult because of the sequence homologies of both α and β subunits to related hormones. The terminal end of the β -chain subunit chain was chosen as a target for RT-PCR since it had the most significant differences compared to other related hormone β -chain subunits.

Initially 24 established human melanoma cell lines derived from different anatomical sites were assessed to determine if they expressed β -HCG chain. Oligo dT₍₁₅₎ priming was carried out to assess only poly A mRNA of β -HCG. Of the 24 cell lines tested by RT-PCR, 16 of 24 produced a specific cDNA product of the correct size (367 bp) as verified by Etbr gel staining.

β -actin was run on all samples as an internal control to verify RNA yield and efficiency of the RT-PCR assay. Each assay had a negative control consisting of RT-PCR reagents alone without RNA and a positive control for β -HCG. Southern blot analysis of PCR cDNA product with the β -HCG probe showed that three of the cell lines negative by Etbr staining had a specific cDNA band. However, one cell line in which the Etbr staining was questionable showed no specific band on Southern blot analysis. Overall 18 out of 24 cell lines were positive (75%) for β -HCG marker expression.

To further verify β -HCG marker expression, endonuclease restriction digestion with *Sty I* was carried out on the RT-PCR cDNA products. All cDNA products digested, produced two bands, 271 bp and 96 bp as

- 50 -

observed on Etbr gels, indicative of β -HCG marker. These digested products were further verified by Southern blot analysis with β -HCG cDNA probe.

5

EXAMPLE VII

Detection of β -HCG mRNA Expression in Melanoma Tumor Biopsy Specimens

A. MATERIALS AND METHODS

10

(i) Melanoma Tumor Biopsy Specimens and Blood Preparation

Melanoma tumor biopsy specimens that were defined by
15 histopathology as malignant melanoma were assessed.
Melanoma biopsies were obtained from primary lesions and
from multiple anatomical sites of metastatic lesions from
different patients. Specimens were immediately frozen or
processed as received from the operating room. In this
20 study liquid nitrogen cryopreserved and fresh tumor
biopsies from surgery were assessed. On obtaining
melanoma biopsies non-melanoma tissue was carefully
dissected away from normal tissue under sterile
conditions in a laminar flow hood.

25

PBL were obtained from 25 normal male and female
volunteer donors and the buffy coat was collected for RNA
isolation as described in Example I. All other
techniques including RT-PCR, Southern blotting and
30 restriction enzyme digests were as described in
Example VI.

Normal axillary lymph node tissue that was assessed
as histopathology negative for tumor was obtained from
35 melanoma and breast cancer patients undergoing elective
surgery. Axillary lymph nodes were assessed by

- 51 -

histopathology for malignancy by standard conventional hematoxylin and eosin (H & E) staining.

B. RESULTS

5

Melanoma primaries and metastases have been shown to contain infiltrating immune cells (Cochran and Hoon, 1987). To be certain that β -HCG mRNA was being expressed by the tumor cells and not a product of infiltrating lymphoid cells, peripheral blood lymphocytes were also analysed for expression of β -HCG mRNA. PBL from 25 normal volunteer donors were analysed by RT-PCR but no evidence of β -HCG expression was observed, even after Southern blot analysis (except in one individual who was positive in a second blood draw).

15

Five lymph nodes from two breast and melanoma patients, were found to be negative by H & E staining and by RT-PCR and Southern blotting.

20

Both cryopreserved and fresh biopsy tissue were analysed by histopathology and by RT-PCR, restriction digestion and Southern blotting. Out of 40 patients, 38 were identified, as melanoma positive by histopathology, while 16 were identified as positive by RT-PCR for β -HCG marker. In other words, an estimated 42% of melanoma biopsies were β -HCG positive. All specimens that were found to be melanoma negative by histopathology, were also negative for β -HCG marker expression. The detection of β -HCG mRNA was much weaker in melanoma biopsy tissues as compared to melanoma cell lines. This detected lower gene activity may be due to the heterogeneity of tumors, variability of host physiologic regulation of β -HCG, or simply the dilution of RNA by normal cell infiltrate.

30

There was no significant difference in β -HCG mRNA detection between cryopreserved and fresh biopsy

35

- 52 -

specimens. β -actin expression was detected in all specimens, thus verifying the integrity of the mRNA and the PCR assay. α -HCG subunit expression in five β -HCG positive melanoma cell lines and five melanoma biopsies was also analyzed. However, no α -HCG expression was detected by RT-PCR even when followed by Southern blot analysis.

EXAMPLE VIII

A Comparison of β -HCG mRNA Expression with Other Melanoma Markers

A. MATERIALS AND METHODS

(i) *Surgical Specimens*

Axillary lymph node tissue was taken after elective surgery of TDLN from seven melanoma patients. TDLN were assessed by histopathology for malignancy by standard conventional hematoxylin and eosin (H & E) staining. β -HCG mRNA expression was compared with tyrosinase and MAGE-3 mRNA expression by RT-PCR. All other materials and methods were as described in Example VI.

B. RESULTS

Out of eight tumor-draining lymph nodes (TDLN) (from seven melanoma patients) five were positive for β -HCG expression, six for tyrosinase and three for MAGE-3. In two patients, none of the markers were detected.

- 53 -

Table 9
Analysis of β -HCG expression in melanoma TDLN

| TDLN | Path | β -actin | β -HCG EtBr | β -HCG S. Blot | β -HCG Sty I | Tyr | MAGE3 |
|--|------|----------------|----------------------|-------------------------|-----------------------|-----|-------|
| 1 | + | + | - | + | + | + | - |
| 2 | + | + | - | + | + | + | - |
| 3 | + | + | - | - | | + | + |
| 4 | + | + | + | + | + | + | + |
| 5 | + | + | - | - | | - | - |
| 6 | + | + | + | + | + | + | + |
| 7a | + | + | + | + | + | + | - |
| 7b | - | + | - | - | | - | - |
| <p>TDLN refer to individual patient nodes examined (a and b refer to two separate nodes). Pathology refers to the hematoxylin and eosin staining histopathology analysis of lymph node sections. + refers to presence of melanoma metastases and - refers to no metastases. RT-PCR analysis detected by Etbr and Southern blot is indicated as + or -. Tyr refers to RT-PCR analysis by tyrosinase primers followed by nested tyrosinase RT-PCR if negative.</p> | | | | | | | |

In conclusion, β -HCG is a useful addition to the group of melanoma markers described in Examples I through V. The frequency of expression of β -HCG mRNA in melanoma appears to be similar to that of the melanoma tumor antigens MAGE-3 and MAGE-1.

EXAMPLE IX

Detection of GalNAc mRNA Expression in Melanoma Cells and Biopsies

A. MATERIALS AND METHODS

(i) Melanoma cell lines and Surgical Specimens

Melanoma cell lines were all established at JWCI and grown as described in Example I. 20 melanoma tumor

- 54 -

biopsy specimens were obtained as described in Example VII. RNA extraction and RT-PCR assay was as described in Example BI.

5 (iv) *Oligonucleotide primers and Probes*

Oligonucleotide primers were synthesized and purified at the Molecular Biology Institute Core Facility, UCLA. The GalNAc primers used were: 5'-
10 CCAACTCAACAGGCAACTAC-3' (SEQ ID NO: 19) and 3'
GATCATAACGGAGGAAGGTC-3' (SEQ ID NO: 20). cDNA probes, amplified by PCR with these primers, were used in Southern blotting, which was performed as described in Example II. The tyrosinase and MAGE-3 primers were the
15 same as described in Example I and β -HCG primers were the same as described in Example VI.

- 55 -

Table 10

GalNAc expression in melanoma biopsies and cell lines

| SPECIMENS | | GalNAc EXPRESSION | | |
|----------------------|---------------------|----------------------|--|--|
| BIOPSIES# METASTASES | | | | |
| 5 | 19 | - | | |
| | 25 | - | | |
| | 68 | - | | |
| | 100 | + | | |
| 10 | 102 | + | | |
| | 178 | - | | |
| | 221 | - | | |
| | 224 | - | | |
| 15 | 246 | + | | |
| | 250 | - | | |
| | 260 | - | | |
| | 261 | - | | |
| 20 | 287 | - | | |
| | 292 | + | | |
| | 295 | + | | |
| | 301 | + | | |
| 25 | 351 | + | | |
| | 361 | + | | |
| | 380 | + | | |
| | 443 | + | | |
| 30 | | | | |
| | MELANOMA CELL LINES | | | |
| | MATT | + | | |
| | M101 | + | | |
| 30 | M12 | + | | |
| | M24 | + | | |
| | M10 | + | | |
| | M18 | + | | |
| | MKN | + | | |

- 56 -

Table 10 (continued)

| | SPECIMENS | GalNAc EXPRESSION | | |
|----|--------------------------------|----------------------|--|--|
| | MHL | + | | |
| | MCE | + | | |
| | MKE | + | | |
| | MELL | + | | |
| 5 | MMAC | + | | |
| | MF | - | | |
| | M18 | + | | |
| | PERIPHERAL BLOOD LYMPOCYTES | | | |
| 10 | DONOR #1 | - | | |
| | DONOR #10 | - | | |
| | DONOR #12 | - | | |
| | DONOR #13 | - | | |
| | DONOR #322 | - | | |
| 15 | DONOR #323 | - | | |
| | DONOR #324 | - | | |
| | DONOR #325 | - | | |
| | DONOR #326 | - | | |
| | DONOR #338 | - | | |
| 20 | DONOR #339 | - | | |
| | DONOR #340 | - | | |
| | DONOR #342 | - | | |
| | DONOR #343 | - | | |
| | | | | |
| 25 | NORMAL LYMPH NODE #349 | - | | |
| | NORMAL LYMPH NODE #364 | - | | |

- 57 -

B. RESULTS

As shown in Table 7, detection of GalNAC mRNA was
succesfully detected in 13 out of 14 melanoma cell lines
5 and 10 out of 20 biopsy specimens. Furthermore, no
GalNac marker expression was observed in normal lymph
nodes or PBL. These are similar results to those found
for β -HCG and MAGE-3 in previous examples. Indicating
that GalNac mRNA expression is another marker which may
10 be utilized for the detection of melanoma and metastases.

Amplification of GalNAC mRNA is an indicator of
gangliosides, GM2 and GD2, expression. Direct detection
of GM2 and GD2 in occult metastases and small tumor
15 lesions such as melanoma primaries is very difficult and
often impractical when using standard biochemical
methods. Monoclonal antibodies to gangliosides are
available but often cross-react with other carbohydrate
structures and therefore are not reliable and do not
20 represent absolute ganglioside expression (Hoon et al.,
1993).

Detection of tumor cells with the marker GalNac by
RT-PCR provides a novel approach to detect metastatic
25 melanoma and breast cancer cells in blood or fluids that
would not be possible by current biochemical or
immunological techniques.

EXAMPLE X**30 Detection of β -HCG mRNA Expression in Breast Cancer Cells****A. MATERIALS AND METHODS***(i) Breast cell lines*

35

The established breast cancer cell line JWCI BM-1
was developed from a primary invasive ductal carcinoma

- 58 -

tumor and characterized as a breast cancer line at the John Wayne Cancer Institute. Breast cell lines MDA-MB-231, MCF-7, BT-549, T-47D and BT-20 were obtained from the American Type Culture Collection (ATCC, Rockville, MD) and were cultured according to instructions provided. The 734B line is an established subclone of MCF-7. Cells were grown in 10% fetal calf serum (heat-inactivated) RPMI 1640 (Gemini Bioproducts, Calabasas, CA) plus penicillin and Streptomycin (GIBCO, Long Island, NY) in T75 cm² flasks. Adherent cell lines were routinely passaged by trypsinization every 3-4 days. When cell lines attained 75-85% confluency they were used for PCR analysis.

15 (ii) RNA preparation

Tri-Reagent (Molecular Research Center, Inc. Cincinnati, OH) was used to isolate total RNA from the cell lines and surgical specimens, following the manufacturer's instructions and described in Example I. One μ g of total RNA was used in the PCR assay to detect β -HCG mRNA. Oligonucleotide primers and probes were as described in Example VI.

25 (iii) RT-PCR

Reverse transcription was as described in Example I, using oligo (dT)₁₅ and oligo nucleotides as described in Example VI.

30 The PCR mixture was also as described in Example I and incubated in an OmniGene temperature cycler (Hybaid, Middlesex, England) at 95°C for 3 min for 1 cycle; 95° C for 1 min, 65°C for 1 min, 72°C for 1 min for 30 cycles; and 72°C for 10 min. The PCR cDNA products were assessed in a 2% agarose gel containing ethidium bromide. A 100 bp DNA ladder (GIBCO BRL Life Technologies Inc.,

- 59 -

Gaithersburg, MD) was used as a bp reference marker. Restriction enzyme digestion and Southern blot analysis were performed as previously described in Example VI.

5 (iv) β -HCG protein expression in breast cancer cells

Breast cancer cells from individual cell lines were seeded in 12 well tissue culture microplates at 2 million cells/well in 1.5 ml of RPMI 1640 without fetal calf
10 serum and cultured at 37°C in a tissue culture incubator for 24 hr. Supernatant was harvested and concentrated 10 times to a volume of 150 μ l using Centricon 10 concentrators (Amicon Division, W.R. Grace & Co., Beverly, MA). β -HCG in the supernatant was measured
15 using a total β -HCG Quantitative Test kit (Medix Biotech Inc., Foster City, CA), following the manufacturer's instructions. Supernatant samples were tested in duplicate with a standard reference for each assay. The ELISA reaction was read at 490 nm using a Vmax kinetic
20 microplate reader (Molecular Devices Corp., Palo Alto, CA).

B. RESULTS

25 (i) β -HCG mRNA expression in breast cell lines

All seven breast cancer cell lines were found to express β -HCG mRNA. A positive result was indicated by a 367 bp cDNA band as detected by Etbr-staining and
30 Southern blot analysis. To confirm the identity of the amplified PCR cDNA product, samples were digested with endonuclease *Sty I*. All seven β -HCG PCR products were cleaved by *Sty I* to produce bands of 271 and 96 bp on Etbr gels, thus confirming β -HCG mRNA expression. As a
35 negative control, PBL from 25 normal (male and female) volunteers were examined. None of the control specimens

- 60 -

were shown to be positive for β -HCG marker expression by PCR and Southern blotting.

The expression of α -HCG mRNA was also examined by
5 PCR in breast cell lines. In cell lines MDA-MB-231, JWC1
BM-1, and T-47D, α -HCG mRNA expression was detected by
Etbr-stained gel electrophoresis. The α -subunit detected
could be HCG or other related hormones since they all
share a high degree of similarity in α -subunit. For this
10 reason α -HCG as a cancer marker, is not practical.

*(ii) β -HCG protein expression in breast cancer cell
lines*

15 Out of the seven breast cell lines expressing β -HCG
mRNA, only three cell lines (MDA-MB-231, T47-D, JWC1 BM-
1) secreted detectable levels of β -HCG protein as
analysed by ELISA (0.15 mIU, 0.15 mIU, 0.1 mIU/ 2×10^6
cells, respectively). The cell lines, producing β -HCG
20 were those that were positive for α -HCG mRNA expression.

Breast cancer lines were also analysed for β -HCG
receptor mRNA. Human β -HCG/LH receptor genes cloned
recently, have been shown to possess a high degree of
25 similarity (Minegish et al., 1990). All cell lines were
positive for β -HCG/LH receptor mRNA expression. To
evaluate whether β -HCG/LH receptor could be used as a
marker for metastatic breast cancers, PBL from six normal
volunteer donors (male and female) was analysed for the
30 corresponding mRNA using the primers as described in
Example VI. All donors expressed β -HCG/LH receptor mRNA
indicating that the β -HCG/LH receptor is not a reliable
marker for detecting breast cancer cells in blood or
lymph nodes.

- 61 -

EXAMPLE XI**Sensitivity of β -HCG Marker****A. MATERIALS AND METHODS**

5

(i) PCR detection sensitivity

The sensitivity of the PCR assay to detect β -HCG mRNA in breast cancer cells was assessed by the following methods:

10

(a) RNA was isolated from MDA-MB-231 cells and serially diluted from 1 to 10^{-6} μ g, and then analysed by the RT-PCR assay.

15

(b) Cell suspension of MDA-MB-231 cells were prepared and diluted with PBL to produce an *in vitro* model occult carcinoma cells in lymph nodes. 10^7 PBL were mixed with a variable number of cancer cells ranging from 1 to 10^5 . Total RNA was then isolated from the mixtures and analysed by the RT-PCR assay and observed on an Etbr gel along side a positive (10^6 MDA-MB-231 cells) and negative (10^7 PBL) control. All other method were as described in Example X. The PBL were obtained from normal volunteers in which PCR analysis had shown no presence of β -HCG mRNA.

20

25

B. RESULTS

30

RT-PCR results of a series of diluted RNA isolated from MDA-MB-231 was determined on Etbr agarose gels. β -HCG marker was detected from as little as 10^{-5} μ g RNA. This detection was enhanced ten fold by Southern blotting, enabling β -HCG mRNA expression detection from as little as 10^{-6} μ g of RNA.

35

- 62 -

Employing the *in vitro* model it was shown that one breast cancer cell, determined by the amplification of β -HCG marker, could be detected up to among 10^7 PBL.

5

EXAMPLE XII**Detection of β -HCG mRNA Expression in
Breast Cancer Specimens**10 **A. MATERIALS AND METHODS***(i) Surgical Specimens*

Thirty-one lymph nodes were collected from 18
15 patients (13 invasive ductal carcinoma, 4 invasive lobular carcinoma, and one *in situ* carcinoma) who were undergoing mastectomy with axillary lymphadenectomy for clinically early stage breast cancer. Nodes that were only logistically practical for cutting, for conventional
20 pathological diagnosis and for archive fixation were obtained for RT-PCR. Patients ranged in age from 37 to 73 years old. In order to compare the results of PCR with histological analysis, the lymph nodes were divided into two, one half was analyzed by PCR and the other by
25 histopathological H & E staining of serial sections.

For a negative control, blood was obtained from 25
normal volunteer donors (both male and female). All
further materials and methods were as described in
30 previous examples.

B. RESULTS

Table 11 shows the results of β -HCG mRNA expression
35 in TDLN. Two TDLN from eleven patients (patient G to Q) and three TDLN from one patient were analysed. Five of the TDLNs were found to be negative by conventional H & E

- 63 -

staining, were found to be positive for β -HCG marker expression in the PCR assay (No. 4, 16, 19, 23, and 24). If the RT-PCR assays were found to be negative, Southern blot analysis was subsequently performed.

5

Overall, 9 out of 31 TDLN were found to be negative by H & E staining and PCR with or without Southern blotting. Four of the TDLN which were found to be negative by both PCR and histological examination, were
10 subsequently found to be positive following Southern blot analysis (No. 12, 13, 15, and 22). All 367 bp β -HCG PCR cDNA products detected by PCR or Southern blotting were digested by restriction enzyme Sty I. There were no TDLN found to be positive by histological examination, but
15 found negative by PCR or PCR and by Southern blotting.

- 64 -

Table 11
Detection for β -HCG expressing tumor cells
in breast TDLN

| | Specimen number | Patient | Tumor histology | Pathology | | PCR | Southern blot |
|----|--------------------|---------|--------------------|-----------|---|-----|------------------|
| 5 | 1 | A | lobular | + | + | | |
| | 2 | B | ductal | + | + | | |
| | 3 | C | ductal | + | + | | |
| | 4 | D | insitu | - | + | | |
| 10 | 5 | E | lobular | + | + | | |
| | 6 | F | ductal | + | + | | |
| | 7 | G | ductal | - | - | | - |
| | 8 | | | - | - | | - |
| | 9 | H | ductal | - | - | | - |
| 15 | 10 | | | + | | + | |
| | 11 | I | ductal | - | - | | - |
| | 12 | | | - | - | | + |
| | 13 | J | ductal | - | - | | + |
| | 14 | | | - | - | | - |
| 20 | 15 | K | ductal | - | - | | + |
| | 16 | | | - | - | | + |
| | 17 | L | ductal | - | - | | - |
| | 18 | | | + | + | | + |
| | 19 | M | ductal | - | + | | |
| 25 | 20 | | | + | + | | |
| | 21 | N | ductal | - | - | | - |
| | 22 | | | - | - | | + |
| | 23 | O | ductal | - | + | | |
| | 24 | | | - | + | | |
| 30 | 25 | P | ductal | + | + | | |
| | 26 | | | + | + | | |
| | 27 | Q | ductal | - | - | | - |
| | 28 | | | - | - | | - |
| | 29 | R | lobular | + | + | | |

Table 11 (continued)

| Specimen number | Patient | Tumor histology | Pathology | PCR | Southern blot |
|--------------------|---------|--------------------|-----------|-----|------------------|
| 30 | | | + | + | |
| 31 | | | + | + | |

Individual patients are labelled as A - R and numbers refer to individual TDLN. Tumor histology represents H & E staining diagnosed pathology. Pathology refers to diagnoses of + or - for breast cancer metastases. PCR results are indicated as + or - on Etbr gel electrophoresis analysis. Specimens negative for RT-PCR assay were subsequently Southern blotted with β -HCG cDNA probe. Southern blot analysis is indicated as + or -.

EXAMPLE XIII

Detection of Breast Cancer Cells by Multiple Markers

A. MATERIALS AND METHODS

(i) Breast cell lines and Surgical Specimens

The breast cell line MDA-MB-231, MCF-7, BT-549, T-47D and BT-20 were obtained from the American Type Culture Collection (ATCC, Rockville, MD) and were cultured according to instructions provided. The 734B line is an established subclone of MCF-7. Cells were grown as described in Example X. 11 breast cancer biopsies were extracted as described in Example XII. RNA extraction and RT-PCR assay were as described in Example X.

(ii) Oligonucleotide primers and Probes

Oligonucleotide primers were synthesized and purified at the Molecular Biology Institute Core Facility, UCLA. The MAGE-1 primer sequences were as follows: 5' primer was 5'-GCTGGAACCCTCACTGGGTTGCC-3' (SEQ ID NO: 23) and the 3' primer was

- 66 -

5'-CGGCCGAAGGAACCTGACCCAG-3' (SEQ ID NO: 24). The RT-PCR cDNA product was 421 bp. The tyrosinase and MAGE-3 primers were the same as described in Example I, β -HCG primers were the same as described in Example VI and GalNAc primers were the same as described in Example IX. cDNA probes, amplified by PCR with these primers, were used in Southern blotting, which was performed as described in Example II.

10 B. RESULTS

Multiple markers were used to analyse breast cancer cells and breast cancer biopsy specimens by RT-PCR and Southern blotting. Tables 12 and Table 13 shows the results. All breast cancer cells were positive for at least five, out of the six, markers. For the biopsy specimens, at least one of the markers were detected from all samples. None of the markers alone would have been able to detect cancer cells in all of the specimens. This variation in marker detection reflects the heterogeneity of tumor cells. In conclusion, multiple markers are more sensitive to detection of breast cancer than any one marker.

25

Table 12

Analysis of Markers in Breast Cancer Cell Lines

30

| | MAGE3 | MAGE 1 | MUC18 | p97 | GalNAc | β-HCG |
|---------|--------------|---------------|--------------|------------|---------------|-------------------------------|
| BT20 | + | + | + | -- | + | + |
| BT549 | + | -- | + | + | + | + |
| 902P | + | + | + | + | + | + |
| T47D | + | + | + | -- | + | + |
| 734B/24 | + | + | + | + | + | + |
| 231/45 | -- | + | + | + | + | + |
| MCF7 | + | + | + | + | + | + |

35

+/-: RT-PCR or Southern Blotting

- 67 -

Table 13

Analysis of Markers in Breast Cancer Biopsies

| | Biopsy tumor or number | GalNAc | β -HCG | MUC 18 | P-97 | MAGE-3 | MAGE-1 |
|----|------------------------|--------|--------------|--------|------|--------|--------|
| 5 | 0350T2A122794 | + | + | + | -- | -- | + |
| | 0424T2A011795 | -- | -- | -- | -- | + | -- |
| | 0433T2A011895 | -- | + | + | -- | + | -- |
| | 044T2A012095 | -- | -- | -- | -- | + | -- |
| | 0460T2A012695 | -- | + | + | -- | + | + |
| 10 | 0498T2K020395 | -- | -- | + | -- | -- | -- |
| | 0500T2K020695 | -- | -- | + | + | + | -- |
| | 0506T2A020795 | + | + | + | + | -- | + |
| | 0520T2A020995 | -- | -- | + | -- | -- | + |
| | 0522T2A020995 | -- | -- | + | -- | -- | -- |
| 15 | 0525T2A020995 | -- | -- | + | + | -- | -- |

+/-: RT-PCR and Southern Blotting

Previous PCR studies have not analyzed large numbers of patients with different clinical stages of melanoma or breast cancer. This is important in evaluating the sensitivity and clinical significance of the assay. Furthermore, this information is useful in staging disease into clinical subgroups, in particular, identifying subgroups of patients that need more intensive therapeutic intervention. For example, in NED patients with circulating tumor cells, immediate therapeutic intervention may be a very efficacious means of controlling potential tumor progression and, thus, preventing clinical disease. The detection of circulating cancer cells may also prove useful for monitoring a patient's response to operative and adjuvant therapies.

- 68 -

Applying a multiple melanoma marker method to the evaluation of circulating cancer cells also provides information about the tumor's phenotype. Identification of specific tumor-associated antigen(s) permits the rational use of specific immunotherapy protocols such as monoclonal antibodies and cancer vaccine (Hoon *et al.*, 1993). The PCR assay also provides a rapid monitoring system as a follow-up to determine if a specific therapy is effective.

10

While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the composition, methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

15
20

- 69 -

REFERENCES

The following references, to the extent that they provide exemplary procedural or other details
5 supplementary to those set forth herein, are specifically incorporated herein by reference.

Acevedo, H.F., Krichevsky, A., Campbell-Acevedo, E.A., Gaylon, J.C., Buffor, M.J., and Hortsock, R.J. Flow
10 cytometry method for the analysis of membrane-associated human chorionic gonadotropin, its subunits, and fragments on human cancer cells. *Cancer*, 69:1818-1828, 1992.

Agnantis, N.J., Patra, F., Khaldi, L., and Filis, S.T.
15 Immunohistochemical expression of subunit beta HCG in breast cancer. *Eur. J. Gynaec. Oncol.*, 13:461-466, 1992.

Alfthan, H., Haglund, C., Roberts, P., and Stenman, U.H. Elevation of free β subunit of human choriogonadotropin and core β fragment of human choriogonadotropin in the
20 serum and urine of patients with malignant pancreatic and biliary disease. *Cancer Res.*, 52:4628-4633, 1992.

American Joint Committee on Cancer, *Manual for Staging Cancer*, Fourth Ed., Lippincott & Co., Philadelphia, PA.
25

Ando, I., Hoon, D.B., Suzuki, Y., Saxton, R.L., Golub, S.H. and Irie, R.F. Ganglioside GM2 on the K562 cell line is recognized as a target structure by human natural
30 killer cells. *Int. J. Cancer* 40:12-17, 1987.

Balch C.M., Soong S.W., Shaw H.M, An analysis of prognostic factors in 4000 patients with cutaneous melanoma. *CUTANEOUS MELANOMA: CLINICAL MANAGEMENT AND*
35 *TREATMENT RESULTS WORLDWIDE*, Balch C.M., Milton G.W. (eds.), Philadelphia, PA, J.B. Lippincott Co. (1985), pp 321-352.

- 70 -

- Bellus, D. How Do Specialty Polymers Modify the Chemical and Pharmaceutical Industries? *J. Macromolecular Science--Pure and Applied Chem*, **A31**(1):1355-1376, 1994.
- 5 Bettelheim, R., Price, K.N., Gelber, R.D., Davis, B.W., Cassigline, M., Goldrisch, A., Neville, A.M. Prognostic importance of occult axillary lymph node micrometastases from breast cancer. *Lancet*, **335**:1565-1568, 1990.
- 10 Bo, M., and Boime, I. Identification of the transcriptionally active genes of the chorionic gonadotropin β -gene cluster *in vivo*. *J. Biol. Chem.*, **267**:3179-3184, 1992.
- 15 Boorstein, W.R., Vamvakopoulos, N.C. and Fiddes, J.C. Human chorionic gonadotropin beta-subunit is encoded by at least eight genes arranged in tandem and inverted pairs. *Nature (Lond.)*, **300**:419-22, 1982.
- 20 Breslow, A., Thickness, cross-sectional area and depth of invasion in the prognosis of cutaneous melanoma. *Ann. Surg.* **172**:902-908, 1970.
- Brown J.P., Nishiyama, K., Hellstrom, I. Structural
25 characterization of human melanoma-associated antigen p97 using monoclonal antibodies. *J. Immunol.* **127**:539-546, 1981.
- Bystryn, J-C., Bernstein, P., Liu, P. Immunophenotype of
30 human melanoma cells in different metastases. *Cancer Res.* **45**:5603-5607, 1985.
- Cantor et al., *Genomics*, **13**:1378, 1992.
- 35 Carubia, M.J., Yu, R.R., Macala, L.J. Kirkwood, J. and Varga, J.M. Gangliosides of normal and neoplastic human

- 71 -

melanocytes. *Biochem. Biophys. Res. Commun.* **120**:500-504, 1984.

- Chen, Z.L., Wen, D.R., Coulson, W.F., Giuliano, A.E., and
5 Cochran, A.J. Occult metastases in the axillary lymph
nodes of patients with breast cancer node negative by
clinical and histologic examination and conventional
histology. *Disease Markers*, **9**:239-248, 1991.
- 10 Clark, W.H. Jr., Elder, D.E., Guerry IV, D. et al. A
study of tumor progression: The precursor lesions of
superficial spreading and nodular melanoma. *Human
Pathol.* **15**:1147-1165, 1984.
- 15 Cole, L.A., Hartle, R.J., Laferla, J.J., and Ruddon, R.W.
Detection of the free β -subunit of human chorionic
gonadotropin (HCG) in cultures of normal and malignant
trophoblast cells, pregnancy sera, and sera of patients
with choriocarcinoma. *Endocrinology*, **113**:1176-1178, 1983.
- 20 Datta, Y.H., Adams, P.T., Drobyski, W.R., Ethier, S.P.,
Terry, V.H. and Roth, M.S. Sensitive detection of occult
breast cancer by the reverse-transcriptase polymerase
chain reaction. *J. Clin. Oncol.* **12**:475-482, 1994.
- 25 Davey et al., EPO No. 329 822.
- Drmanac & Crkvenjakov, U.S. Patent No. 5,202,231.
- 30 Edbooke et al., *EMBO J.* **4**:715-724.
- Elder, D.E., Rodeck, U., Thurin, J. Pigmented lesion-
associated antigens distinguish between benign and
malignant melanocytic lesions. *Cancer Res.* **49**:5091-5096,
35 1989.

- 72 -

Erlich, H.A. (ed). *PCR TECHNOLOGY: PRINCIPLES AND APPLICATIONS FOR DNA AMPLIFICATION*. Stockton, New York, NY (1989).

5 Fiddes, J.C., and Goodman H.M. Isolation, cloning and sequence analysis of the cDNA for the alpha-subunit of human chorionic gonadotropin. *Nature (Lond.)*, **281**:351-356, 1979.

10 Fidler, I.J. Critical Factors in the biology of human cancer metastasis: Twenty-eighth G.H.A. Clowes Memorial Award Lecture. *Cancer Res.* **50**:6130-6138, 1990.

Fidler, I.J. and Hart, I.R. Biologic diversity in
15 metastatic neoplasms origins and implications. *Science* **217**:998-1001, 1982.

Fisher, E.R., Swamidoss, S., Lee, C.H., Rockette, H.,
Redmond, C., and Fisher, B. Detection and significance of
20 occult axillary node metastases in patients with invasive breast cancer. *Cancer*, **42**:2025-2031, 1978.

Fitzpatrick, T.B. Skin Cancer. In: The American Cancer Society Cancer Handbook. Ch. 30, pp. 532-547, Doubleday
25 & Co., Garden City, NY (Arthur I. Holleb, M.D., ed.) 1986.

Forrest, A.P. Screening and breast cancer incidence. *J. Natl. Cancer Inst.*, **82**:1525, 1990.

30 Friedman, L.S., Ostermeyer, E.A., Lynch, E.D., Szabo, C.I., Anderson, L.A., Dowd, P., Lee, M.K., Rowell, S.E., Boyd, J. and King, M.C. The search for BRAC1. *Cancer Res.*, **54**:6374 - 6382, 1994.

35

- 73 -

Freifelder, D. *Physical Biochemistry Applications to Biochemistry and Molecular Biology*. 2nd ed. Wm. Freeman & Co., New York, NY, 1982.

- 5 Frohman, M.A., *PCR PROTOCOLS: A GUIDE TO METHODS AND APPLICATIONS*, Academic Press, N.Y. (1990).

10 Furukawa, K., Akagi, T., Nagata, Y., Yamada, Y., Shimotohno, K., Cheung, N-K, Shiku, H., Furukawa, K. GD2 ganglioside on human t-lymphotropic virus type I-infected T cells: Possible activation of β -1,4-N-acetylgalactosaminyltransferase gene by p40tax. *Proc. Natl. Acad. Sci. (USA)* **90**:1972-1976, 1993.

- 15 Gazdar et al., 1988, *Cancer Research* **48**:4078-4082.

Gaugler, B., Van den Eynde, B., van der Bruggen, P. Human gene MAGE-3 codes for an antigen recognized on a melanoma by autologous cytolytic T lymphocytes. *J. Exper. Med.* **179**:921-930, 1994.

20

Gingeras et al., PCT Application WO 88/10315.

- 25 Giuliano, A.E., Kirgan, D.M., Guenther, J.M., and Morton, D.L. Lymphatic mapping and sentinel lymphadenectomy for breast cancer. *Ann. Surgery*, **220**:391-401, 1994.

30 Giuliano, A.E., Breast. In: Tierney, L.M.Jr., McPhee, S.J., and Papadakis, M.A. (eds.) *Current Medical Diagnosis and Treatment*. 34th ed. pp.593-616 Appelton and Lange, Norwalk, CT., 1995.

- 35 Giuliano, A.E., Breast Disease. In: J.S. Bereck and N.A. Haker (eds.) *Practical Gynecological Oncology*. pp.481-515. Williams & Wilkins, Baltimore, 1994.

- 74 -

Hainsworth, P.J., Tjandra, J.J., Stillwell, R.G., Machet, D., Henderson, M.A., Rennie, G.C., McKenzie, I.F. and Bennett R.C. Detection and significance of occult metastases in node-negative breast cancer. *Br. J. Surg.*,
5 80:459-463, 1993.

Henderson, I.C. Adjuvant systemic therapy: Stage of the art, 1989. *Breast Cancer Res. Treat.*, 14:3-22, 1989.

10 Hoon, D.S.B., Hayashi, Y., Morisaki, T. Interleukin-4 plus tumor necrosis factor α augments the antigenicity of melanoma cells. *Cancer Immunol. Immunother.* 37:378-384, 1993.

15 Hoon, D.S.B., Okun, E., Neuwirth, H., Morton, D.L., Irie, R.F. Aberrant expression of gangliosides in human renal cell carcinomas. *J. Urol.*, 150(6):2013-2018, 1993.

Hoon, D.S.B., Wang, Y., Sze L. Molecular cloning of a
20 human monoclonal antibody reactive to ganglioside GM3 antigen on human cancers. *Cancer Res.* 53:5244-5250, 1993.

Hoon, D.S.B., Ando, I., Sviland, G., Tsuchida, T., Okun, E., Morton, D.L., and Irie, R.F. Ganglioside GM2
25 expression on human melanoma cells correlates with sensitivity to lymphokine-activated killer cells. *Int. J. Cancer* 43:857-862, 1989.

30 Hoon, D.S.B., Korn, E.L., and Cochran, A.J. Variations in functional immunocompetence of individual tumor-draining lymph nodes in humans. *Cancer Res.*, 47:1740-1744, 1987.

Hoon, D.S.B., Bowker, R.J, and Cochran, A.J. Suppressor
35 cell activity in human breast cancer draining lymph nodes. *Sur. Res. Comm.*, 9:167-176, 1990.

- 75 -

- Hoon, D.S.B., Banez, M., Okun, E., Morton, D.L., and Irie, R.F. Modulation of human melanoma cells by interleukin-4 and in combination with gamma interferon or α -tumor necrosis factor. *Cancer Res.* 51:2002-2008, 1991.
- 5 Innis et al., *PCR Protocols*, Academic Press, Inc., San Diego CA (1990).
- Irie, R.F., Tai, T. and Morton, D.L. Antibodies to tumor associated gangliosides (GM2 and GD2): Potential for suppression of melanoma recurrence. In: M. Torisu and T. Yoshida (eds), *Basic mechanisms and clinical treatment of tumor metastasis*, pp. 371-384, Academic Press, Tokyo, 1985.
- 10
- 15 Jacoby, D.R., Olding, L.B., Oldstone, M.B.A. Immunologic regulation of fetal-maternal balance. *Adv. Immunol.*, 35:157-208, 1984.
- 20 Jonas et al., 1985, *Proc. Natl. Acad. Sci. USA* 82:1994-1998
- Kaiser, H.E. Characteristics and pattern of direct tumor spreading. *LOCAL INVASION AND SPREAD OF CANCER*. K.W. Brunson (ed.), Netherlands, Kluwer Academic (1989), pp 1-16.
- 25
- Kayser et al., 1988, *Pathology Research and Practice* 183(4):412-417.
- 30
- Kayser et al., 1988, *Pathology Research Practice* 143:412-417.
- Khrapko et al., *J. DNA Sequencing Mapping* 1:375, 1991.
- 35
- Konecki et al., 1987, *JBC* 262:17026-17030.

- 76 -

Kwoh et al., *Proc. Nat. Acad. Sci. USA* 86:1173, 1989.

Kwon B.S., Haq A.K., Pomerantz S.H. Isolation and
sequence of a cDNA clone for human tyrosinase that maps
5 at the mouse c-albino locus. *Proc. Nat'l Acad. Sci. USA*
84:773-7477, 1987.

Kwon, B.S. Pigmentation genes: the tyrosinase gene
family and the pmel 17 gene family. *J Invest. Dermatol.*,
10 100(2 Suppl):134S-140S, 1993.

Lagios, M.D., Westdahl. P.R., Margolin, F.R., and Rose,
M.R. Duct carcinoma in situ. Relationship of extent of
noninvasive disease to the frequency of occult invasion,
15 multicentricity, lymph node metastasis, and short-term
treatment failures. *Cancer*, 50:1309-14, 1982.

Lehmann, J.M., Riethmuller, G., Johnson, J.P. MUC18, a
marker of tumor progression in human melanoma, shows a
20 sequence similarity to the neural cell adhesion molecules
of the immunoglobulin superfamily. *Proc. Nat'l Acad.*
Sci. USA 86:9891-9895, 1989.

Lehmann, J.M., Holzmann, B., Breitbart, E.W.
25 Discrimination between benign and malignant cells of
melanocytic lineage by two novel antigens, a glycoprotein
with a molecular weight of 113,000 and a protein with a
molecular weight of 76,000. *Cancer Res.* 47:841-845,
1987.

30 Madersbacher S, Kratzik C, Gerth R, Dirnhofer S and
Berger P. Human chorionic gonadotropin (HCG) and its free
subunits in hydrocele fluids and neoplastic tissue of
testicular cancer patients: Insights into the *in vivo*
35 hCG-secretion pattern. *Cancer Res.*, 54:5096-5100, 1994.

- 77 -

- Marcillac, I., Troalen, F., Bidart, J.M., Ghillani, P., Ribrag, V., Escudier, B., Malassagne, B., Droz, J.P., Lhomme, C., Rougier, P., Duvillard, P., Prade, M., Lugagne, P.M., Richard, F., Pynard, T., Bohuon, C.,
5 Wands, J., and Bellet, D. Free human chorionic gonadotropin β -subunit in gonadal and nongonadal neoplasms. *Cancer Res.*, **52**:3901-3907, 1992.
- Martin et al., Recent Progress in Hormone Research
10 **45**:467-506, 1989.
- McManus, LM., Naughton, MA., and Martinez-Hernandez, A. Human chorionic gonadotropin in human neoplastic cell. *Cancer Res.*, **36**:3476-3481, 1976.
15
- Miller et al., PCT Application WO 89/06700.
- Minegishi, T., Nakamura, K., Takakura, Y., Miyamoto, K., Hasegawa, Y., Ibuki, Y., and Igarashi, M. Cloning and
20 sequencing of human LH/hCG receptor cDNA. *Biochem. Biophys. Res. Commun.*, **172**:1049-1054, 1990.
- Moertel, C.G., Fleming, T.R., MacDonald, J.S. An evaluation of the carcinoembryonic antigen (CEA) test for
25 monitoring patients with resected colon cancer. *J. Amer. Med. Assoc.* **270**:943-947, 1993.
- Moreno, J.G., Croce, C.M., Fisher, R. Detection of hematogenous micrometastasis in patients with prostate
30 cancer. *Cancer Res.* **52**:6110-6112, 1992.
- Morisaki, T., Yuzuki, D.H., Lin, R.T. Interleukin 4 receptor expression and growth inhibition of gastric carcinoma cells by interleukin 4. *Cancer Res.* **52**:6059-
35 6065, 1992.

- 78 -

Morton, D.L., Wong, J.H., Kirkwood, J.M. Malignant melanoma in *CANCER MEDICINE* (3rd Ed.), Holland, J.F., Frei III, E., Bast Jr., C.C. (eds). Lea & Febiger, Philadelphia, PA (1993) pp. 1793-1824.

5

Morton, D.L., Davtyan, D.G., Wanek, L.A. Multivariate analysis of the relationship between survival and the microstage of primary melanoma by Clark's level and Breslow thickness. *Cancer* 71:3737-3743, 1993.

10

Morton, D.L., Foshag, L.J., Hoon, D.S.B. Prolongation of survival in metastatic melanoma after active specific immunotherapy with a new polyvalent melanoma vaccine. *Ann. Surgery* 216:463-482, 1992.

15

Moyle, W.R. and Campbell, R.K. Gonadotropins. In: *Endocrinology*, 3rd ed., L.J. DeGroot et al (eds), Part II, Neuroendocrinology, W.B.Saunders Co., Philadelphia. pp. 230-241, 1993.

20

Mullis, K.B., Faloona, F. Specific synthesis of DNA in vitro via a polymerase-catalyzed chain reaction. *Methods Enzymol.* 155:335-350, 1987.

25

Nagata, Y., Yamashiro, S., Yodoi, J., Lloyd, K.O., Shiku, H. and Furukawa, K. Expression cloning of β -1,4 N-acetylgalactosaminyltransferase cDNAs that determine the expression of GM2 and GD2 gangliosides. *J. Biol. Chem.* 267:12082-12089, 1992.

30

Naito, H., Kuzumaki, N., Uchino, J. Detection of tyrosine hydroxylase mRNA and minimal neuroblastoma cells by the reverse trasncription-polymerase chain reaction. *Eur. J. Cancer* 27:762-765, 1991.

35

Natali et al., *Cancer* 59:55-63, 1987.

- 79 -

Neville, A.M., Price, K.N., Gelber, R.D., and Goldhirsch, A. Axillary node micrometastases and breast cancer. *Lancet*, 337:1110, 1991.

- 5 Nicolson, G.L. Paracrine/autocrine growth mechanisms in tumor metastasis. *Oncology Res.* 4:389-399, 1993.

- NIH consensus Development Conference. NIH-Consensus Statement, 1992
Nordlund, J.J., Abdel-Malek, Z.A., Boissy, R.E. Pigment cell biology: an historical review. *J. Invest. Dermatol.* 92:53S-60S, 1989.
- 10

- Neville, A.M. Breast cancer micrometastases in lymph nodes and bone marrow are prognostically important. *Ann. Oncology*, 2:13-14, 1991.
- 15

- Noguchi, S., Aihara, T., Nakamori, S., Motomura, K., Inaji, H., Imaoka, S., and Koyama, H. The detection of breast carcinoma micrometastases in axillary lymph nodes by means of reverse transcriptase-polymerase chain reaction. *Cancer*, 74:1595-1600, 1994.
- 20

- Nowell, P.C. Genetic instability in cancer cells: relationship to tumor cell heterogeneity. *TUMOR CELL HETEROGENEITY*, Owens, A.H., Coffey, D.S., Baylin, S.B. (eds.). New York, Academic Press (1982) pp. 351-365.
- 25

- Ohara et al., *Proc. Nat'l Acad. Sci. USA*, 86:5673-5677, 1989.
- 30

- Oliver, R.T.D., Nouri, A.M.E., Crosby, D., Iles, R.L., Navarette, C., Martin, J., Bodmer, W., and Festenstein, H. Biological significance of beta hCG, HLA and other membrane antigen expression on bladder tumors and their relationship to tumor infiltrating lymphocytes (TIL). *J. Immunogenet.*, 16:381-390, 1989.
- 35

- 80 -

Perez and Walker, 1990, *J. Immunol.* **142**:3662-3667, and
Bumal, 1988, *Hybridoma* **7**(4):407-415.

Pierce, J.G. and Parsons, T.F. Glycoprotein hormones:
5 structure and function. *Annu. Rev. Biochem.*, **50**:465-495,
1981.

Ricketts, RM., and Jones, DB. Differential effect of
human chorionic gonadotrophin on lymphocyte proliferation
10 induced by mitogens. *J. Reproductive Immunology*, **7**:225-
232, 1985.

Rose, T.M., Plowman, G.D., Teplow D.B. Primary structure
of the human melanoma-antigen p97 (melanotransferrin)
15 deduced from the mRNA sequence. *Proc. Nat'l Acad. Sci.*
USA **83**:1261-1265, 1986.

Rothman, P.A., Chao, V.A., Taylor, M.R., Kuhn, R.W.,
Jaffe, R.B. and Taylor, R.N. Extraplacental human fetal
20 tissues express mRNA transcripts encoding the human
chorionic gonadotropin- β subunit protein. *Mol. Reprod.*
Dev. **33**:1-6, 1992.

Russell et al., *Mol. Cell Endocrin.* **71**(1):1-12, 1990.
25

Saiki, R.K., Gelfand, D.H., Stoffel, S., Scharf, S.J.,
Higuchi, R., Horn, G.T., Mullis, K.B., and Erlich, H.A.
Primer-directed enzymatic amplification of DNA with a
thermostable DNA polymerase. *Science*, **239**:487-491, 1988.
30

Sambrook, J., Fritsch, E.F., Maniatis, T. (ed.).
MOLECULAR CLONING. Cold Spring Harbor Lab. Press, Cold
Spring Harbor, NY (1989).

35 Scanlon and Strax. Breast Cancer. In: The American
Cancer Society Cancer Book. Ch. 17, pp. 297-340,

- 81 -

Doubleday & Co., Garden City, NY (Arthur I. Holleb, M.D., ed.) 1986.

Sedmak, D.D., Meineke, T.A., and Knechtges, D.S.

- 5 Detection of metastatic breast carcinoma with monoclonal antibodies to cytokeratins. *Arch. Pathol. Lab. Med.*, 113:786 -789, 1989.

Selby, W.L., Mance, K.U., and Vork, H., CEA

- 10 immunoreactivity in metastatic malignant melanoma. *Modern Path.* 5:415-419, 1992.

Shuh, M.E., Nemoto, T., Penetrante, R.B., Rosner, D., and
15 Dao T.L. Intraductal carcinoma. Analysis of presentation, pathologic findings, and outcome of disease. *Arch. Surgery*, 121:1303-1307, 1986.

Smart, C.R. Screening and early cancer detection. *Sem. Oncol.* 17:456-462, 1990.

20

Smith, B., Selby, P., Southgate, J. Detection of melanoma cells in peripheral blood by means of reverse transcriptase and polymerase chain reaction. *Lancet* 338:1227-1229, 1991.

25

Sobol et al., *Annals of Internal Medicine* 105(5):698700, 1986.

Southern, PCT Application No. WO 89/10977.

30

Southern et al.. *Genomics* 13:1008, 1992.

Spindel et al., *Proc. Natl. Acad. Sci. USA* 83:19-23, 1986.

35

Stamey, T.A., Kabalin, J.N., McNeal, J.E. Prostrate-specific antigen in the diagnosis and treatment of

- 82 -

adenocarcinoma of the prostate. *J. Urol.* **141**:1076-1083, 1989.

Strezoska et al. *Proc Natl. Acad. Sci.* **88**:10089, 1991.

5

Suva, *Gene* **77**(1):95-105, 1989.

Talmadge, K., Vamvakopoulos, N.C. and Fiddes, J.C.
Evolution of the genes for the β -subunit of human
10 chorionic gonadotropin and luteinizing hormone. *Nature*,
307:37-40, 1984.

Tormey, D.C., Waalkes, T.P., and Simon, R.M. Biological
markers in breast carcinoma. II. Clinical correlations
15 with human chorionic gonadotropin. *Cancer*, **39**:2391-2396,
1977.

Tormey, D.C., Waalkes, T.P., Ahmann, D., Gehrke, C.W.,
Zunwatt, R.W., Snyder, J., and Hansen, H. Biological
20 markers in breast carcinoma. I. Incidence of
abnormalities of CEA, HCG, three polyamines, and three
minor nucleosides. *Cancer*, **35**:1095-1100, 1975.

Torres, J.V., Yoshioka, N., and Atassi, M.Z. Antigenic
25 regions on the β -chain of human chorionic gonadotropin
and development of hormone specific antibodies. *Immunol.*
Invest., **16**:607-618, 1987.

Tsuchida, T., Saxton, R.E. and Irie, R.F. Gangliosides
30 of human melanoma: GM2 tumorigenicity. *J. Natl. Cancer*
Inst. **78**:45-54, 1987.

Tsuchida, T., Saxton, R.E. and Irie, R.F. Gangliosides
of human melanoma: GM2 tumorigenicity. *J. Natl. Cancer*
35 *Inst.* **78**:55-60, 1987.

- 83 -

Vijayasardahi et al., *J. Experimental Medicine*
171(4):1375-1380, 1990.

Walker et al., *Proc. Nat'l Acad. Sci. USA* 89:392-396,
5 1992.

Walker, M.J., Ronan, S.G., Han, M.C., Beattie, C.W. and
Das Gupta, T.K. Interrelationship between histopathologic
characteristics of melanoma and estrogen receptor status.
10 *Cancer* 68:184-188, 1991.

Wu et al., *Genomics* 4:560, 1989.

Yamaguchi, A., Ishida, T., Nishimura, G., Kumaki, T.,
15 Katoh, M., Kosaka, T., Yonemura, Y., and Miyazaki, I.
Human chorionic gonadotropin in colorectal cancer and its
relationship to prognosis. *Br. J. Cancer*, 60:382-384,
1989.

20 Yoshimura, M., Nishimura, R., Murotani, A., Miyamoto, Y.,
Nakagawa, T., Hasegawa, K., Koizumi, T., Shii, K., Baba,
S., and Tsubota, N. Assessment of urinary β -core fragment
of human chorionic gonadotropin as a new marker of lung
cancer. *Cancer*, 73:2745-2752, 1994.

- 84 -

SEQUENCE LISTING

(1) GENERAL INFORMATION:

5

(i) APPLICANT:

- (A) NAME: John Wayne Cancer Institue
(B) STREET: 2200 Santa Monica Boulevard
(C) CITY: Santa Monica
10 (D) STATE: California
(E) COUNTRY: United States of America
(F) POSTAL CODE (ZIP): 90404
- (A) NAME: National Genetics Institute
15 (B) STREET: 5839 Green Valley Circle, Suite 104
(C) CITY: Culver City
(D) STATE: California
(E) COUNTRY: United States of America
(F) POSTAL CODE (ZIP): 90230

20

(ii) TITLE OF INVENTION: DETECTION OF MELANOMA OR
BREAST METASTASES WITH A
MULTIPLE MARKER ASSAY

25

(iii) NUMBER OF SEQUENCES: 24

(iv) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
30 (C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Version
#1.30 (EPO)

35

(v) CURRENT APPLICATION DATA:

APPLICATION NUMBER: UNKNOWN

(vi) PRIOR APPLICATION DATA:

- 85 -

(A) APPLICATION NUMBER: USSN 08/406,307

(B) FILING DATE: 17-MAR-1995

5 (2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 18 base pairs

(B) TYPE: nucleic acid

10 (C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

15 GAAGCCGGCC CAGGCTCG

18

(2) INFORMATION FOR SEQ ID NO: 2:

20 (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 23 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

25

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

GGAGTCCTCA TAGGATTGGC TCC

23

30

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 22 base pairs

35 (B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

- 86 -

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

CCAAGGCAAC CTCAGCCATG TC 22

5

(2) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 25 base pairs
- 10 (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

15

CTCGACTCCA CAGTCTGGGA CGACT 25

(2) INFORMATION FOR SEQ ID NO: 5:

20

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- 25 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

GTCATCTTCC GTGTGCGCCA 20

30

(2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:

- 35 (A) LENGTH: 25 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single

- 87 -

(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

5 GTAGCGACCT CCTCAGGCTC CTTAC 25

(2) INFORMATION FOR SEQ ID NO: 7:

10 (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

15

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

TTGGCAGATT GTCTGTAGCC 20

20

(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

25 (B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

30

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

AGGCATTGTG CATGCTGCTT 20

(2) INFORMATION FOR SEQ ID NO: 9:

35

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 20 base pairs

- 88 -

- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

5 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

GTCTTTATGC AATGGAACGC

20

10 (2) INFORMATION FOR SEQ ID NO: 10:

 (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- 15 (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

20 GCTATCCCAG TAAGTGGACT

20

 (2) INFORMATION FOR SEQ ID NO: 11:

25 (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 24 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

30

 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

TACCTGGTGG AGAGCGGCCG CCTC

24

35

 (2) INFORMATION FOR SEQ ID NO: 12:

- 89 -

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

AGCGTCTTCC CCATCAGTGT 20

(2) INFORMATION FOR SEQ ID NO: 13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

ATGCCACCCT GGCTGTGGAG AA 22

(2) INFORMATION FOR SEQ ID NO: 14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 14:

GGGAGTCGGG ATGGA CTGG AA 22

- 90 -

(2) INFORMATION FOR SEQ ID NO: 15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 15:

10

AAAGGAGCGC CATGGATTAC

20

(2) INFORMATION FOR SEQ ID NO: 16:

15

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 16:

CCATTACTGT GACCCTGTTA

20

25

(2) INFORMATION FOR SEQ ID NO: 17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

35

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 17:

CCCGATGTGC TCCTGAACCA GA

22

- 91 -

(2) INFORMATION FOR SEQ ID NO: 18:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 18:

10

GCTGACACCG ACAAGGGGCA A

21

(2) INFORMATION FOR SEQ ID NO: 19:

15

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
20 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 19:

25

CCAACTCAAC AGGCAACTAC

20

(2) INFORMATION FOR SEQ ID NO: 20:

(i) SEQUENCE CHARACTERISTICS:

- 30 (A) LENGTH: 20 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 20:

35

GATCATAACG GAGGAAGGTC

20

- 92 -

(2) INFORMATION FOR SEQ ID NO: 21:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 21:

10

GGAGCAATGA TCTTGATCTT C

21

(2) INFORMATION FOR SEQ ID NO: 22:

15

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
20 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 22:

CCTTCCTGGG CATGGAGTCC TG

22

25

(2) INFORMATION FOR SEQ ID NO: 23:

(i) SEQUENCE CHARACTERISTICS:

- 30 (A) LENGTH: 23 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 23:

GCTGGAACCC TCACTGGGTT GCC

23

- 93 -

(2) INFORMATION FOR SEQ ID NO: 24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 22 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 24:

10

CGGCCGAAGG AACCTGACCC AG

22

- 94 -

CLAIMS:

1. A method for detecting melanoma or breast cancer cells in a biological sample comprising the step of
5 amplifying at least two nucleic acids in said sample, said nucleic acids being melanoma or breast cancer markers.
- 10 2. The method of claim 1, comprising the steps of:
- (a) extracting RNA from said sample;
 - (b) contacting said RNA with a primer pair that
15 hybridize to one of said melanoma or breast cancer marker nucleic acids;
 - (c) amplifying said melanoma or breast cancer marker nucleic acids to produce an
20 amplification product;
 - (d) detecting said amplification product; and
 - (e) repeating steps (b), (c), (d) and (e) with a
25 primer pair that hybridize to at least one of the other said melanoma or breast cancer marker nucleic acids.
- 30 3. The method of claim 2, further comprising the step of preparing at least two pairs of primers complementary to regions of said melanoma or breast cancer marker nucleic acids.

35

- 95 -

4. The method of claim 3, wherein primer pairs for at least three melanoma or breast cancer markers are employed.

5

5. The method of claim 4, wherein primer pairs for at least four melanoma or breast cancer cell markers are employed.

10

6. The method of claim 5, wherein primer pairs for at least five melanoma or breast cancer markers are employed.

15

7. The method of claim 6, wherein primer pairs for at least six melanoma or breast cancer cell markers are employed.

20

8. The method of claim 7, wherein primer pairs for at least seven melanoma or breast cancer cell markers are employed.

25

9. The method of claim 2, wherein said melanoma or breast cancer cell markers are selected from the group comprising; tyrosinase, MAGE-3, MUC18, p97, MAGE-1, GalNAc and β -HCG.

30

10. The method of claim 2, wherein said amplification is polymerase chain reaction.

35

11. The method of claim 10, wherein said polymerase chain reaction is nested.

- 96 -

12. The method of claim 2, wherein said RNA is total cellular RNA.

5

13. The method of claim 12, further comprising the step of converting said RNA to cDNA.

10

14. The method of claim 1, wherein said sample is comprised of a body tissue or body fluid.

15

15. The method of claim 14, wherein said body fluid, comprising: peripheral blood, lymph fluid, ascites, serous fluid, pleural effusion, sputum, cerebrospinal fluid, lacrimal fluid, stool or urine.

20

16. The method of claim 14, wherein said body tissue, comprising bone marrow aspirate, bone marrow biopsy, lymph node aspirate, lymph node biopsy, spleen tissue, fine needle aspirate, skin biopsy or organ tissue biopsy.

25

17. The method of claim 2, wherein said detecting is by gel electrophoresis.

30

18. The method of claim 2, wherein said detecting is by chromatography.

35

19. The method of claim 17, further comprising the step of Southern blotting.

- 97 -

20. The method of claim 1, wherein said sample is of human origin.

5 21. A kit for use in detecting melanoma or breast cancer cell cells in a biological sample comprising:

(a) pairs of primers for amplifying nucleic acids
corresponding to the genes for tyrosinase,
10 MAGE-3, MUC18, p97, MAGE-1, GalNAc and β -HCG;
and

(b) containers for each of said primers.

15

22. The kit of claim 21, further comprising enzymes and reagents for the preparation of cDNA's.

20 23. The kit of claim 21, further comprising enzymes and reagents for radiochemical or chromophoric labeling of nucleic acids.

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 96/03442

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12Q1/68 C12P19/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| X | WO,A,94 00603 (THE TRUSTEES OF PRINCETON UNIVERSITY) 6 January 1994 see page 10, line 26 - page 11, line 8 --- | 1-3, 10-20 |
| X | AMERICAN JOURNAL OF CLINICAL PATHOLOGY, vol. 94, no. 4, October 1990, page 507 XP000576592 COX C ET AL: "tumor marker sensitivity single versus multiple markers in patients with breast carcinoma" see abstract 77 --- | 1-3, 10-20 |
| X | ISREAL JOURNAL OF MEDICAL SCIENCES, vol. 17, no. 9-10, September 1981, pages 865-8, XP000576568 SULITZEANU D: "markers in breast cancer" see the whole document --- | 1-3, 10-23 |
| | --- -/-- | |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

18 July 1996

Date of mailing of the international search report

29.07.96

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer

Osborne, H

INTERNATIONAL SEARCH REPORT

Intern. Application No.

PC1/US 96/03442

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| X | IMMUNOLOGY SERIES, vol. 53, 1990, pages 39-54, XP000576588 MERCER D.: "use of multiple markers to enhance clinical utility" see page 44, paragraph 6 - page 46, paragraph 1 --- | 1-3, 10-20 |
| X | GYNECOLOGICAL AND OBSTETRIC INVESTIGATION, vol. 34, no. 2, 1992, pages 65-72, XP002008750 FARGHALY S.: "tumor markers in gynecologic cancers" abstract and page 71 --- | 1-3, 10-20 |
| A | THE LANCET, vol. 338, 16 November 1991, pages 1227-9, XP002008751 SMITH B. ET AL: "detection of melanoma cells in peripheral blood by means of reverse transcriptase and polymerase chain reaction" see the whole document --- | 1,23 |
| A | EP,A,0 520 794 (F. HOFFMANN LA-ROCHE AG) 30 December 1992 see the whole document --- | 1,23 |
| A | WO,A,90 09456 (BALAZS) 23 August 1990 see claims 1-13 ----- | 1-3 |

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/03442

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| WO-A-9400603 | 06-01-94 | AU-B- 4544393 | 24-01-94 |
| | | AU-B- 4545193 | 24-01-94 |
| | | CA-A- 2137822 | 06-01-94 |
| | | EP-A- 0654092 | 24-05-95 |
| | | JP-T- 8500729 | 30-01-96 |
| | | WO-A- 9400601 | 06-01-94 |
| ----- | | | |
| EP-A-520794 | 30-12-92 | AU-B- 662906 | 21-09-95 |
| | | AU-B- 1846592 | 07-01-93 |
| | | CA-A- 2072314 | 27-12-92 |
| | | JP-A- 5269000 | 19-10-93 |
| ----- | | | |
| WO-A-9009456 | 23-08-90 | EP-A- 0458831 | 04-12-91 |
| ----- | | | |